RAFFERTY-ALAMEDA PROJECT

ENVIRONMENTAL IMPACT STATEMENT

Souris Basin
Development
Authority

CHAPTER 6

HYDROGEOLOGY

RAFFERTY/ALAMEDA ENVIRONMENTAL IMPACT STATEMENT

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HYDROGEOLOGY

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Hydrogeologic units which occur in the study area include buried valley deposits of the Estevan and Weyburn Valley aquifers, the Ravenscrag Formation and Drift. The base of the Ravenscrag Formation or top of the Riding Mountain Formation is regarded as the base of groundwater exploration.

The Estevan and Weyburn hydrogeologic units are important aquifers as they have a high yield potential. At some locations where these aquifers underlie the Souris Valley , they are discharging to surface. Filling of the Rafferty reservoir will decrease the amount of groundwater discharge. Pumping from these aquifers in conjunction with filling the Rafferty Reservoir will induce downward movement of water. Total induced recharge from the Rafferty reservoir is estimated to be in the order of 17 lps (520 Dam^3/year).

In terms of development as a potable water supply, the Ravenscrag Formation is an important aquifer in the study area . In the Rafferty area the Ravenscrag Formation subcrops in the Souris Valley. Filling of the proposed reservoir will benefit the Ravenscrag Aquifer since there could be a theoretical increase in the hydraulic head in this aquifer up to a distance of 10 kilometers from the proposed reservoir. Near the proposed Alameda reservoir the Ravenscrag Formation is the most important aquifer for a source of groundwater. Beneath the Alameda reservoir the till sequence overlying the Ravenscrag formation is about 50-60 m thick and as a result filling of the reservoir will have very little effect on the groundwater regime.

The Drift hydrogeological unit extends across the study area. This unit is composed mainly of till but includes numerous small sand and gravel aquifers and the more extensive Tableland Aquifer. This aquifer, if hydraulically connected to the Rafferty reservoir, may benefit the greatest from this project as the volumes of induced recharge could be significant during initial filling of the Rafferty Reservoir. Water levels in the Tableland aquifer could be affected at a distance of up to 30 kilometers or more and the aquifer could receive as much as 3600 Dam^3/year in the form of induced recharge. The Tableland Aquifer may be very important in providing bank storage for the proposed Rafferty dam.

The proposed Rafferty - Boundary diversion channel will have little effect on the groundwater regime. With groundwater allowed to pond during periods of non-use, water levels may not decline more than 2-3 metres immediately adjacent to the channel. The radius of influence should not spread much more than 200 metres and groundwater losses to evaporation should not exceed more than 43 Dam^3/year. Seepage losses in the channel are estimated to be 1.8 Dam^3 per week of operation. There are no water supplies that

may be adversely affected by the construction and operation of the diversion channel.

In the Alameda reservoir area several wells are completed in surficial and intertill sand and gravels. In some cases these aquifers may extend laterally to the reservoir and may benefit from the new source of recharge.

Because of the anticipated head buildup in the Ravenscrag Aquifer it is believed that increases in soil salinity may occur in the Souris Valley Flood plain up to a distance of 2100 metres below the dam. There is a possibility that this increase in soil salinity may be controlled by pumping from a basal aluvial sand and gravel deposit found under most of the Souris Valley in the study area. Below the proposed Alameda dam, no salinity problems are expected because of high permeability of the Valley aluvium.

The quality of groundwater in the buried valley aquifers, Ravenscrag Formation and Drift, is regarded as poor and if not mixed with better quality water (ie: surface runoff) it generally is unsuitable for irrigation. As a source of good quality recharge water, the Rafferty and Alameda reservoirs should improve groundwater quality except for initial but temporary problems with salinity and agriculturally related chemicals.

Monitoring systems should be installed in each of the major aquifer systems to observe the effects of the proposed reservoirs. The aluvium below both dams should be investigated to determine their ability to naturally dissipate the increased head conditions or to provide conditions for dewatering.

Additional test drilling should be conducted at the Rafferty and Alameda damsites to evaluate the potential for leakage through drift aquifers. This is not an uncommon occurence in situations when dams are built under these geologic conditions and if such an occurence were to present itself suitable mitigative alternatives could be taken. Mitigative measures that could be employed at the Rafferty and Alameda damsites are dewatering wells, seepage control clay blankets, and with shallow seepage zones cutoff trenches would be effective.

APPENDIX ONE

DETAILED HYDROLOGICAL ASSESSMENT

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6.1 INTRODUCTION

Hydrogeology is important baseline information because of the need to evaluate the potential groundwater environmental impacts from the proposed Rafferty and Alameda reservoirs, and the proposed Rafferty - Boundary diversion channel during their construction, operation and abandonment. Impacts of reservoirs could take the form of changes in groundwater flow and, water levels, and changes in groundwater quality.
The hydrogeological assessment was designed to allow for:

- the definition of the principal aquifers, groundwater flow patterns and groundwater quality in the region;
- estimates of changes in the groundwater flow regime in the principal aquifers.
- recommendations regarding groundwater monitoring in the vicinity of Rafferty and Alameda reservoirs.

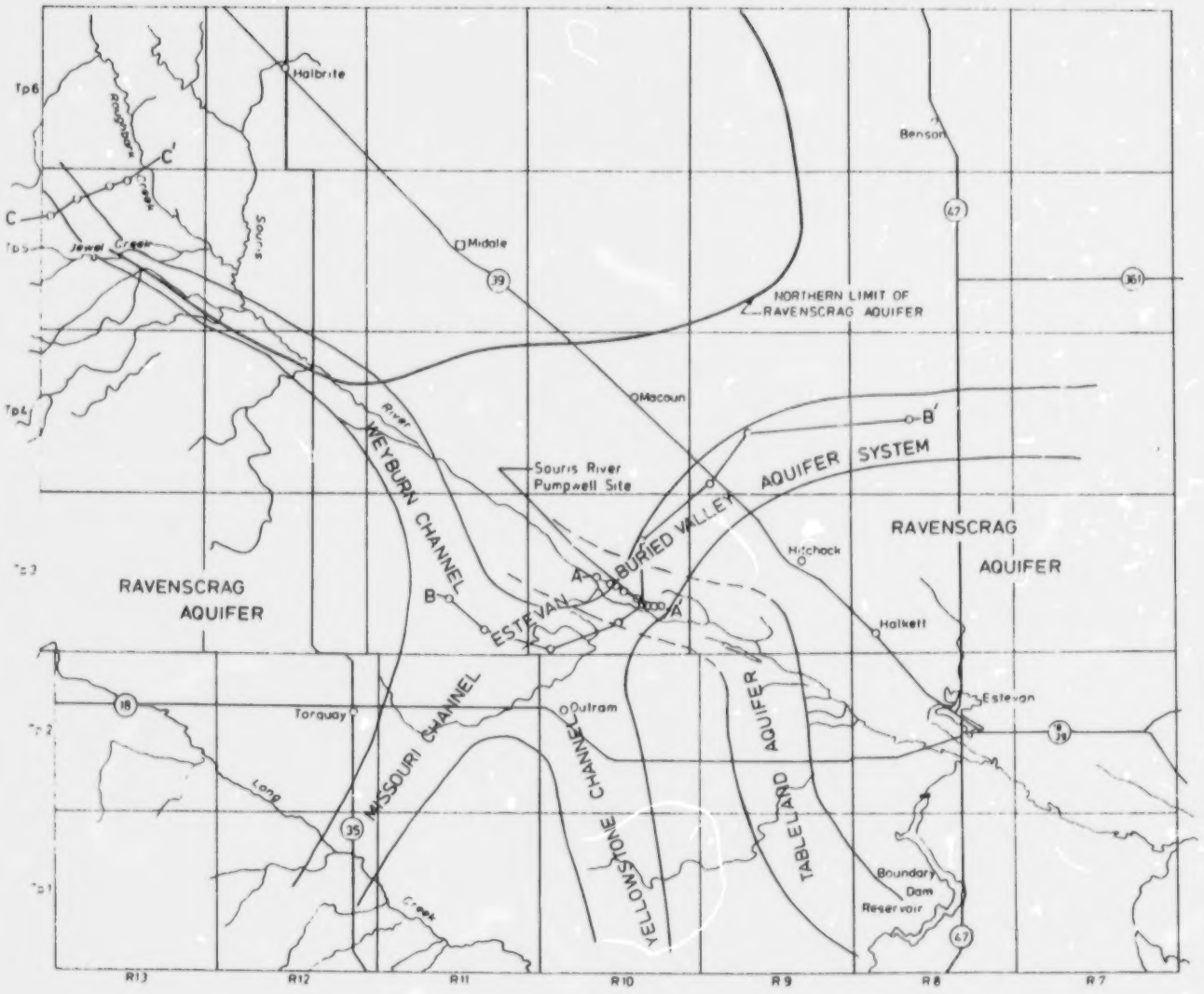
6.2 METHODS

All hydrogeologic description and assessments are based on existing information. The description of the existing environment was based on a background report prepared for the Souris Basin Development Authority by Saskmont Engineering (1986). Major sources of information include reports by Hardy Associates (1985), Beckie Hydrogeologists Ltd. (1983 and 1985), the Souris River Basin Study (Puodziunas, 1977), van der Kamp (1985), Meneley (1983) and the Saskatchewan Water Corporation. The study included the areas covered by and adjacent to the proposed Rafferty and Alameda reservoirs site so that the relationship between the proposed developments and the surrounding areas could be evaluated.

6.3 DESCRIPTIVE HYDROGEOLOGY

Within the study area there are three main hydrogeologic units that will be affected by the proposed develcpments: buried valleys, bedrock and drift. The buried valley deposits and Ravenscrag bedrock units are important regional aquifers and in most cases, interact to form an integrated aquifer system.

The extent of the hydrogeologic units near Rafferty reservoir is apparent from the aquifer location map shown in Figure 6-1. The Estevan and Weyburn buried valleys, which converge near Outram (2-10-W2), contain coarse-grained sand and gravel deposits near their base. The bedrock Ravenscrag Formation, including the Eastend, Whitemud and Frenchmen Formations, constitutes another important hydrogeologic unit and aquifer. Overlying the bedrock and buried valley hydrogeologic



5 0 10 kilometers

RAFFERTY RESERVOIR
LOCATIONS OF MAJOR AQUIFERS
AND
GEOLOGIC CROSS - SECTIONS
A - A to C - C

FIGURE 6-1

BECKIE HYDROGEOLOGISTS LTD.

units is a mantle of drift. The drift is mainly till which confines the other hydrogeologic units, but there are many minor stratified drift deposits and at least one extensive deposit which are important to the total groundwater resources of the study .

631 ESTEVAN VALLEY HYDROGEOLOGIC UNIT

The geology and hydrogeology of the Estevan Buried Valley aquifer have been described in studies by Meneley (1972), Christiansen and Pariezek (1961), Walton (1964 and 1970), Whitaker (1974) and more recently by Beckie (1983 and 1985) and van der Kamp (1985). In most of these reports the Estevan valley aquifer has been described as coarse-grained sand and gravel deposits located at the base of a bedrock valley which extends from the International border south of Outram and runs east to the Saskatchewan - Manitoba border and beyond. The deposits of sand, gravel and associated silt and clay occurring between the till and bedrock have been called the Empress Group (Whitaker and Christiansen (1972).) and may be preglacial, originating from the northwest area of the U. S. A..

For the purposes of this report the unit includes the southwest and southeast extensions of the bedrock valley into the U.S.A. (named by most as the Missouri and Yellowstone Valley aquifers respectively). The Weyburn Valley hydrogeologic unit, which runs northwestward from near Outram towards Weyburn, is discussed separately. In reality, all of the buried valley units maybe interconnected and behave as a single hydrogeologic unit.

The extent of the Estevan aquifer is shown in Figure 6-1 . The Estevan aquifer appears to extend eastward towards the Manitoba border. However, van der Kamp (1985) shows that hydraulic continuity between the aquifer at Oxbow (1-3-2-W2) and an observation well at 16-4-8-W2 is not proven. The Rafferty reservoir will cross over the Estevan Valley Aquifer at 15-3-10W2, while the Alameda Reservoir will be located approximately twenty kilometers to the north.

In most places, the Estevan Valley Aquifer is bordered or underlain by the Ravenscrag Formation, which is much less permeable. Whitaker (1974) indicates the Riding Mountain Formation underlies the Estevan aquifer to the north of Hitchcock (3-9-W2). The aquifer consists of a lower and upper unit separated by a layer of silt or clay of varying thickness (Beckie, 1985) and except near the Souris River Valley is overlain by an aquitard comprised mostly of glacial till with some minor units of silts, clays and interbedded sands . The thickness of this aquitard varies from about 40 to over 100 metres (van der Kamp, 1985). Two cross-sections (Figures 6-2 and 6-3), the locations of which are shown on Figure 6-1, illustrate the nature of the aquifer in the vicinity of the Souris River.

Recent investigations have attempted to determine the yield potential of the aquifer. High capacity test wells have been completed and pump tested near Macoun (Macoun site) at SW5-4-9-W2 and close to the Souris River (Souris site) at NW11-3-10-W2 (Beckie, 1983 and 1985). A computer model has been developed for the Estevan valley aquifer system by the Saskatchewan Research Council (van der Kamp, 1985). By means of the model, the maximum long-term yield from the Macoun site and Souris site production wells has been estimated to be at least 3800 dam^3/year and it may be as high as 8400 dam^3/year. The following values of aquifer parameters were selected for use in the model as giving the best fit to pump test data from the Souris well: channel transmissivity of 720 m^2/day, storage coefficient of 2.4×10^{-4}, hydraulic resistance of 2.9×10^6 days and Ravenscrag Formation transmissivity of 2 m^2/day.

The pumping test at the Souris site determined that the cone of water level depression originating at the well spread rapidly under the Souris River channel. Leakage from the Souris River channel and flood plain sediments had no detectable influence on the observed drawdown in the buried channel deposits (Beckie, 1985). Leakage or drawdown of the water table was also considered by van der Kamp (1985) who demonstrates that the maximum flow rate from the water table down through the aquitard to the aquifer is about 10mm or 2 percent of annual precipitation.

632 WEYBURN VALLEY HYDROGEOLOGIC UNIT

The Weyburn valley hydrogeologic unit was first discovered in the Weyburn area by J.D. Mollard and Associates (1964a). This hydrogeologic unit, like the Estevan hydrogeologic unit, is an important aquifer. The geology and hydrogeology of this aquifer have been described by Mollard and Associates (1964a and b), Whitaker (1974), Puodziunas (1977) and more recently by Beckie (1985) and Hardy Associates (1985). The Weyburn hydrogeologic unit or Weyburn valley aquifer refers to coarse-grained deposits located in a valley incised in bedrock and covered primarily with till. The bedrock valley aquifer extends southeastward from the north and west of Weyburn and appears to join the Estevan valley aquifer near Outram.

The extent of the Weyburn aquifer is shown on Figure 6-1. The precise location of the bedrock channel has not been defined in some places and recent test drilling programs have resulted in changes to the previously supposed location of the channel in the Goodwater area (5-13-W2) and near its confluence with the Estevan valley. The bedrock topography map presented by Hardy Associates (1985) represents the most current version of bedrock topography and location of associated buried aquifers.

The aquifer is bordered or underlain by the Riding Mountain Formation for most of its length, except near its confluence with the Estevan channel where it is underlain by the Ravenscrag

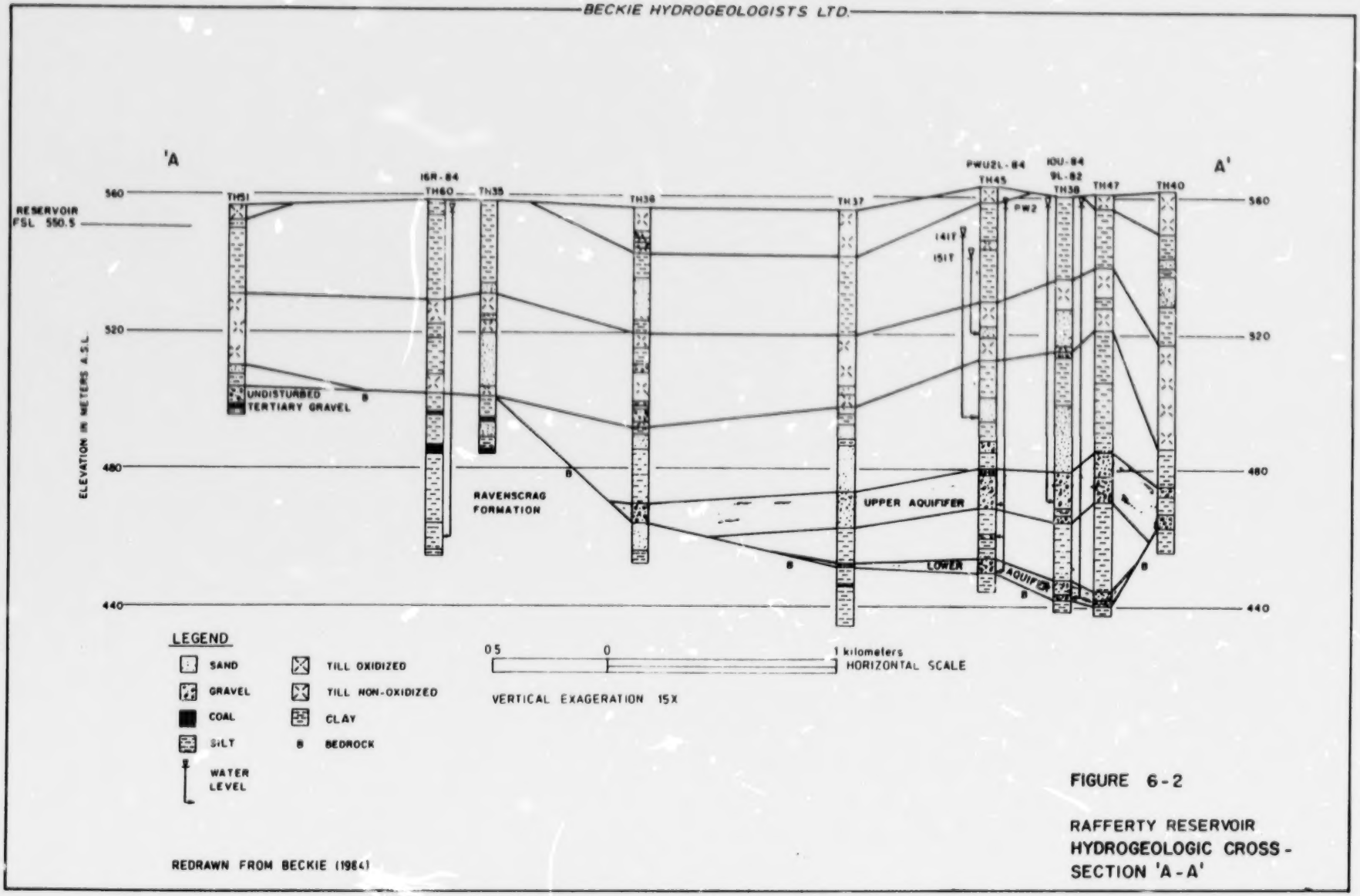
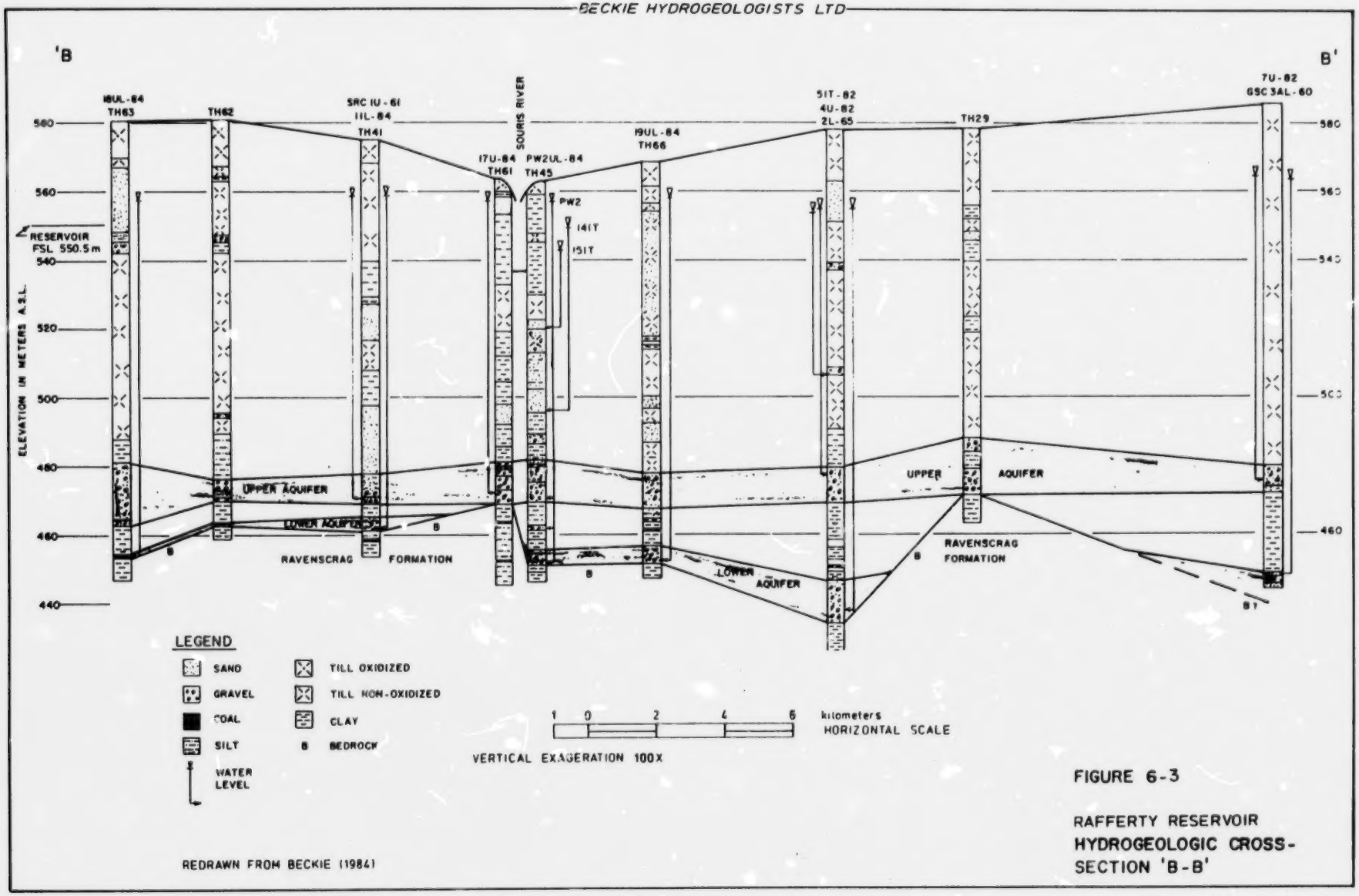


FIGURE 6-2

RAFFERTY RESERVOIR
HYDROGEOLOGIC CROSS-SECTION 'A-A'



REDRAWN FROM BECKIE (1984)

FIGURE 6-3

RAFFERTY RESERVOIR
HYDROGEOLOGIC CROSS-SECTION 'B-B'

Formation which in turn is more permeable than deposits of the Riding Mountain Formation. As in the case of the Estevan valley aquifer, an upper and lower unit have been identified (Mollard, 1964a and 1964b and Beckie 1985).

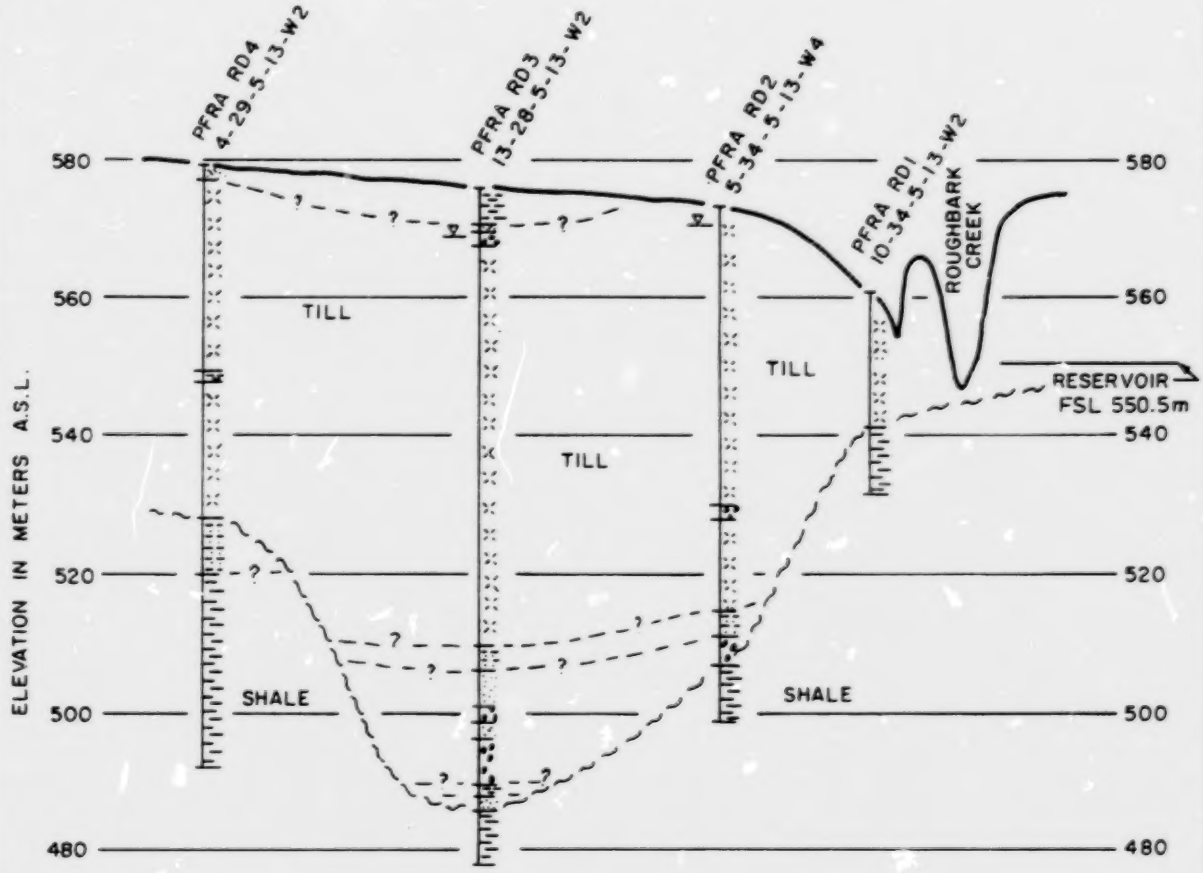
The aquifer is overlain by an aquitard comprised mostly of glacial till. A cross section, Figure 6-4, the location of which is shown in Figure 6-1, illustrates the nature of the aquifer in the vicinity of the Souris River near Goodwater.

The Weyburn Valley Aquifer, near its southern end, has been shown to be in hydraulic continuity with the Estevan aquifer. This has been determined from the drawdown of water in an SRC observation well at Outram caused by a flowing seismic shot hole located near Midale. Also, pumping tests at the Souris site resulted in observed drawdown in the aquifer in 3-11-W2 (Beckie, 1985). Although these observations show hydraulic continuity between the aquifer near Weyburn and the Estevan aquifer has not actually been proven. The proposed Rafferty reservoir will overlie the Weyburn Valley Aquifer over a length of about 9 kilometers in an area south of Midale and towards Weyburn (see Figure 6-1).

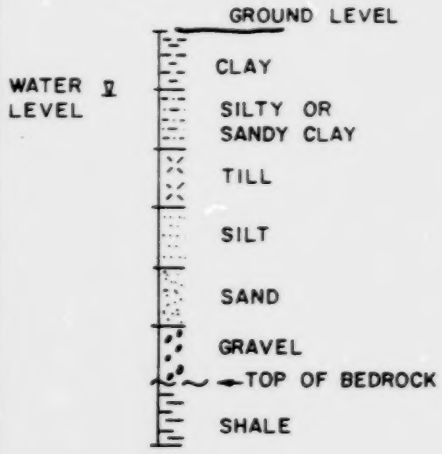
633 RAVENSCRAG BEDROCK HYDROGEOLOGIC UNIT

Except for the most western area of this study the Ravenscrag Aquifer is a very important hydrogeologic unit. For the purpose of this review, the Ravenscrag aquifer includes the Tertiary Ravenscrag and underlying Frenchman, Whitemud, and Eastend Formations. These formations are similar, comprising interbedded fine sands, silts and clays. The Ravenscrag Formation also includes lignite seams which are mined near Estevan. The aquifer is overlain by glacial drift and is underlain by the Pierre Formation which is the uppermost part of Riding Mountain Formation. The top of the latter formation is considered the base of groundwater exploration in view of the Formation's low permeability and poor water quality.

The aquifer surface is a broad featureless plain except where the Estevan and Weyburn buried valleys and the Souris River Valley have been incised. The base of the Ravenscrag aquifer dips southward towards the Williston basin and reaches its maximum thickness in 1-6-W2. The geology and hydrogeology of the Ravenscrag Formation have been described by Meneley (1983). In that report the hydraulic conductivity of the Ravenscrag Formation in the study area is reported to range between 2.0×10^{-2} m/day and 1.7×10^{0} m/day. In the Coronach area the Ravenscrag to Frenchman Aquifers is reported (IJC, 1979) to have a hydraulic conductivity ranging from 9.8×10^{-1} to 1.2×10^{0} m/day and a storage coefficient of 2.8×10^{-4} to 1×10^{-3}. In the vicinity of the proposed Alameda reservoir the Ravenscrag Bedrock hydrogeologic unit is the most important aquifer. It varies in thickness between about 25-75m (Meneley, 1983) and is overlain by



LEGEND



SCALES: HORIZONTAL - 1:50000
VERTICAL - 1:1000

REDRAWN FROM HARDY (1985)

FIGURE 6-4

RAFFERTY RESERVOIR
HYDROGEOLOGIC CROSS-SECTION 'C-C'

about 80m of mainly till (Figure 6-5).

634 DRIFT HYDROGEOLOGIC UNIT

The drift hydrogeologic unit is mainly till resting on bedrock. Glacial sand and gravel occur immediately below the land surface, between tills and between till and bedrock. Pre-glacial sand and gravel between the till and bedrock occurs mainly along the Estevan and Weyburn valleys and have been described separately. Intertill sands and gravels constitute minor aquifers.

Surficial and intertill drift aquifers within the study area can be expected to be extremely variable in nature and location, and have only limited extent and thickness, therefore, it is difficult to predict their occurrence and hydraulic properties . However, in the northern portion of the study area, they are important as they constitute the only possible aquifers where the Riding Mountain Formation forms the uppermost bedrock.

.1 Tableland Aquifer

Water well and testhole data from the records of the Saskatchewan Water Corporation suggest that a subtill aquifer of significant extent may exist over area covering Townships 1, 2, and 3 of R9W2 and the bottom half of Township 1-R8W2 (see Figure 6-1). Meneley (1983) indicates a large subtill sand and gravel deposit crossing the Souris Valley near Lake MacDonald and the author has encountered similar deposits west of Boundary Dam Reservoir (1-3W2) while conducting test drilling for the Saskatchewan Power Corporation. At this location the sand and gravel is up to 30 metres thick, appears to be very permeable and in the authors opinion likely belongs to the Empress Formation.

Although the continuity, extent and hydraulic properties of the above described aquifer are largely unknown, this particular drift aquifer may be significantly affected by the proposed Rafferty reservoir. For purposes of this study this aquifer will be referred to as the Tableland Aquifer. The Tableland Aquifer, based on present information, could extend as indicated on Figure 6-1, which would explain the thick sequences of sand and gravel above the Estevan Valley Aquifer shown on cross-sections A-A' and B-B' (see Figure 6-2 and 6-3).

For purposes of evaluating what effect the Rafferty reservoir may have on the Tableland aquifer it is assumed to have hydraulic properties similar to the Estevan Valley aquifer with a conductivity of about 18 m/day and an average thickness of 20 m.

635 GROUNDWATER FLOW PATTERNS

The regional groundwater flow system is shown on Figure 6-6.

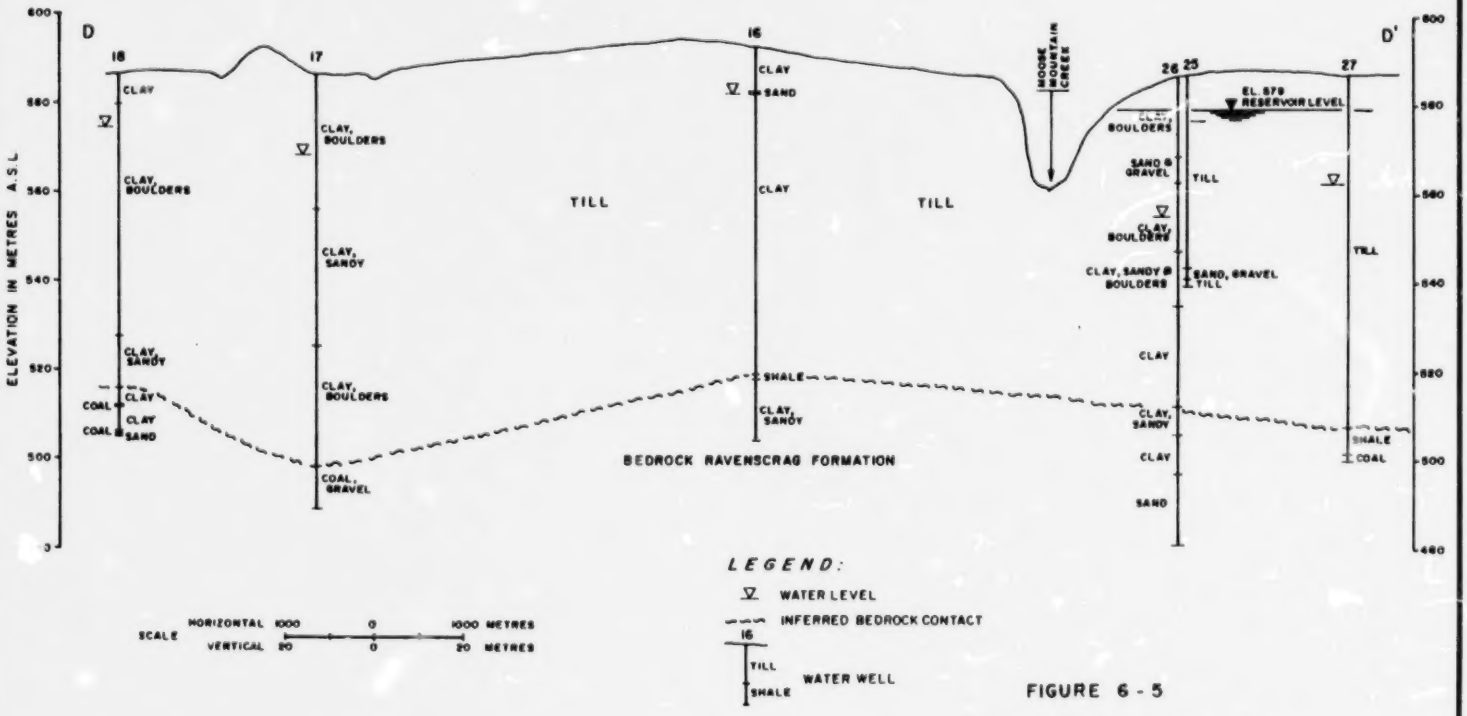


FIGURE 6 - 5

ALAMEDA RESERVOIR

HYDROGEOLOGIC CROSS-SECTION D-D'

SOURCE: SASKMONT ENGINEERING

Vertically infiltrating precipitation is intercepted by pervious units and flow is then laterally to areas of discharge. The Estevan and Weyburn Valley aquifers are the dominant elements through which most of the lateral groundwater flow takes place.

The physiography of the Souris River basin largely controls the flow system within the basin. Puodziunas (1977), referring to the work of Toth (1963), notes that in areas like the Weyburn plain intermediate flow systems are likely to dominate. In such flow systems, the precipitation which reaches the water table moves under the influence of gravity to discharge areas which are further away than local sloughs and streams. The Souris River and Moose Mountain Creek and their tributaries would be likely discharges for intermediate flow systems.

The hydraulic head maps shown on Figures 6-7, 6-8 and 6-9 indicate that subsurface flow is toward the major surface drainage systems where groundwater is believed to be discharging. This interpretation is supported by the potentiometric surface mapped by Stewart (1983). Stewart shows groundwater flows towards the Souris River valley and Moose Mountain Creek. Stewart (1983) shows several water wells, test holes or seismic shot holes, which have flowed at one time, close to the Souris River in 3-10-W2 and at several other locations downstream as far as Oxbow 3-2-W2. Above-river-level heads were also observed in piezometers installed near the river near the Souris pump test site (Beckie, 1985).

These observations indicate that groundwater moves laterally through the bedrock and drift towards the Souris River and Moose Mountain Creek where it slowly discharges as a baseflow contribution. In addition to this baseflow contribution, which is suggested but not verified by any of several writers, groundwater also discharges to the sand and gravel of the buried Estevan and Weyburn valley aquifers. The amount of lateral flow will depend on the horizontal gradient, saturated thickness and hydraulic conductivity of the bedrock and drift material. Figure 6-7 shows the Tableland Aquifer efficiently draining a large area into the Souris Valley suggesting it possesses a relatively higher hydraulic conductivity. As noted previously, flowing wells and drillholes and piezometer readings indicate that vertical gradients are upward beneath most of the Souris River within the study area.

Observations of hydraulic heads within the Weyburn and Estevan valleys aquifers indicate a low horizontal gradient exists between the aquifer near Weyburn and Outram (Hardy Associates, 1985). Beckie (1985) also noted a north to south hydraulic gradient in the Weyburn aquifer. Additional potentiometric

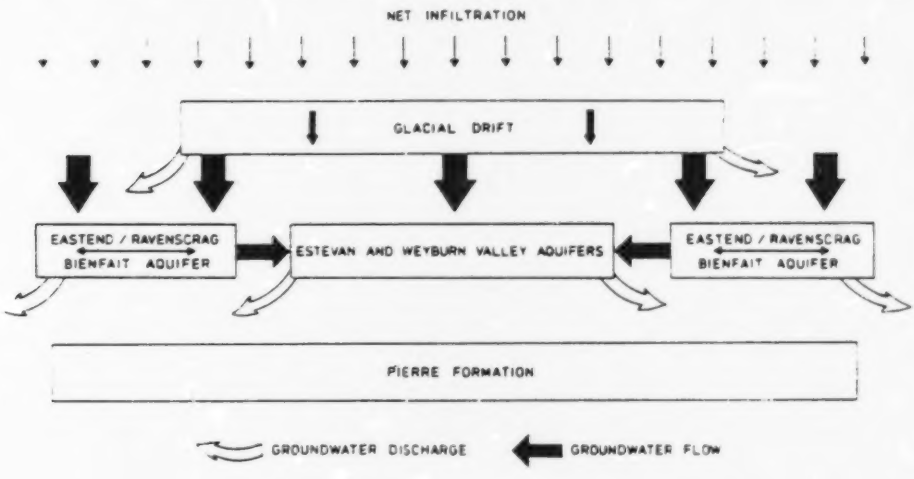


Figure 6-6 Schematic diagram of groundwater flow system in the study area, (redrawn after Meneley, 1983)

observations recorded by Beckie (1985) indicate low hydraulic gradients in a northerly direction in the Missouri and Yellowstone channels (considered as Estevan aquifer in this report) towards the Outram area and thence eastward with slight depression at the Souris Valley indicating upward discharge.

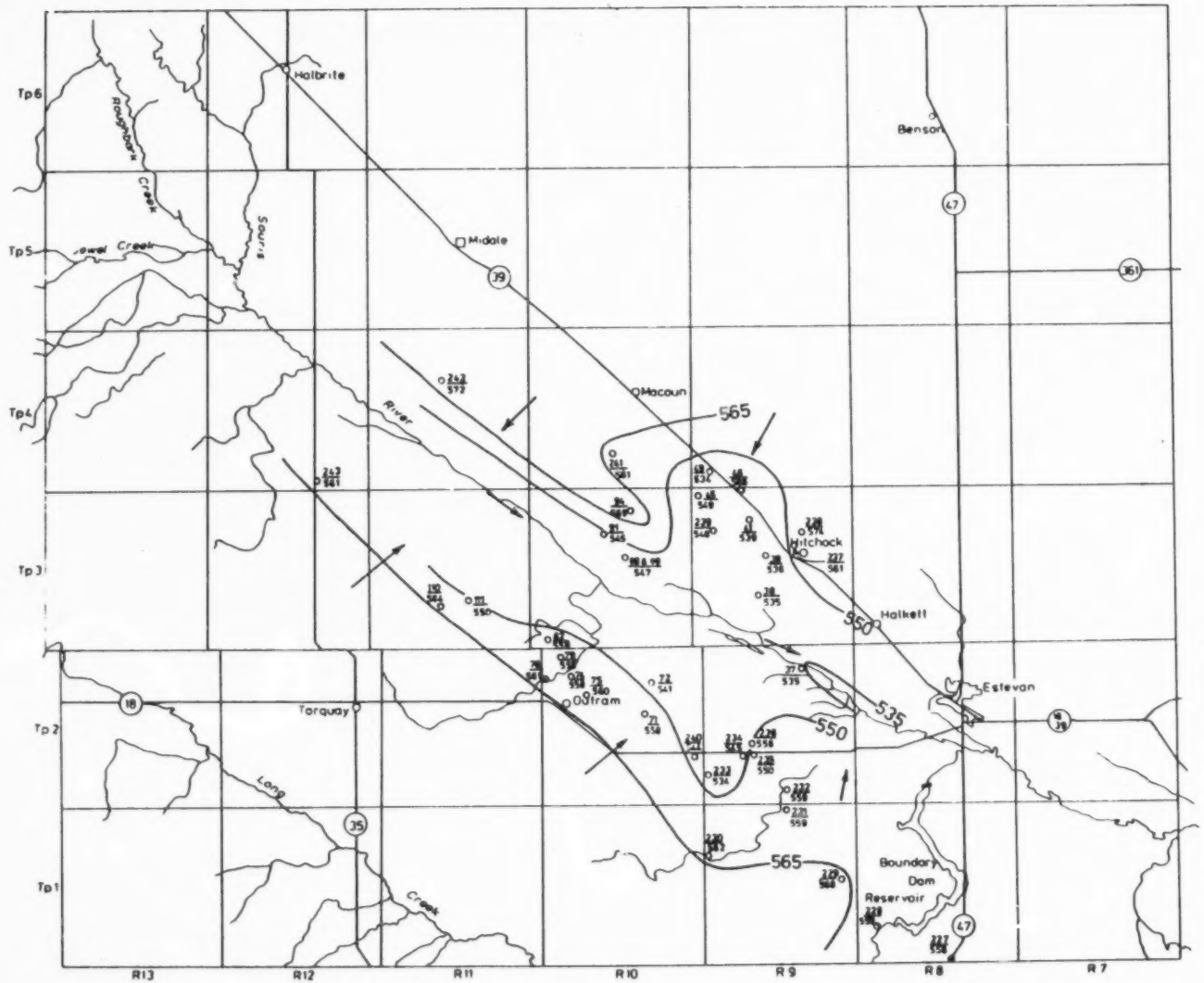
636 HYDROCHEMISTRY

Groundwater data from the major aquifers in the Souris River basin is available in the Souris River Basin Study (Puodziunas, 1977). Additional sources of information include data collated by Meneley (1983), the results of water sampling conducted during pumping tests by Beckie (1983 and 1985) and information available from Saskatchewan Water Corporation on water well records and from Saskatchewan Research Council. Some of the data in these sources used in this report section is from areas outside the immediate study area. No wells were sampled directly as part of this program.

The dissolved constituents in the groundwater are described in terms of water quality criteria under the heading of Groundwater Quality and in terms of their chemical characteristics under the heading of Major Ion Chemistry.

.1 Groundwater Quality

Puodziunas (1977) attempted to determine a relationship



LEGEND

Hydraulic Head Contours

243 / 15 Well Inventory No. / Hydraulic Head M.A.S.L.

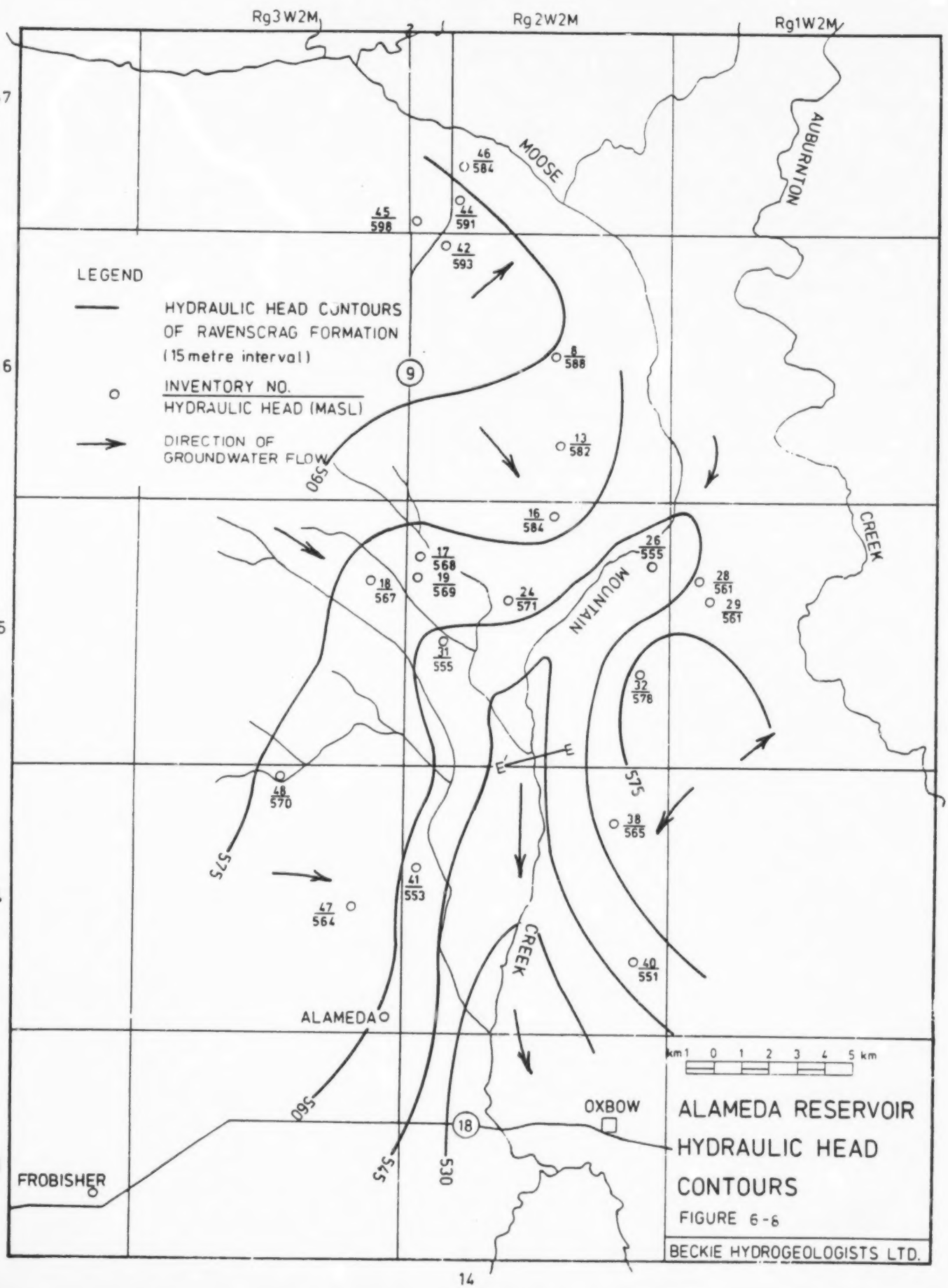
Direction of Groundwater Flow

5 0 10 k ometers

FIGURE 6-7

RAFFERTY RESERVOIR
HYDRAULIC HEAD CONTOURS
AND
DIRECTION OF GROUNDWATER FLOW

BECKIE HYDROGEOLOGISTS LTD.


Rg3W2M
Rg2W2M
Rg1W2M
MOOSE
AUBURNTON
CREEK
MOUNTAIN
CREEK
ALAMEDA
OXBOW
FROBISHER
LEGEND
HYDRAULIC HEAD CONTOURS OF RAVENSCRAG FORMATION (15 metre interval)
INVENTORY NO.
HYDRAULIC HEAD (MASL)
DIRECTION OF GROUNDWATER FLOW
46/584
45/598
44/591
42/593
8/588
13/582
16/584
17/568
19/569
18/567
24/571
26/555
28/561
29/561
31/555
32/578
48/570
47/564
41/553
38/565
40/551
590
575
560
545
530
575
E
E'
9
18
km 1 0 1 2 3 4 5 km
ALAMEDA RESERVOIR
HYDRAULIC HEAD
CONTOURS
FIGURE 6-6
BECKIE HYDROGEOLOGISTS LTD.

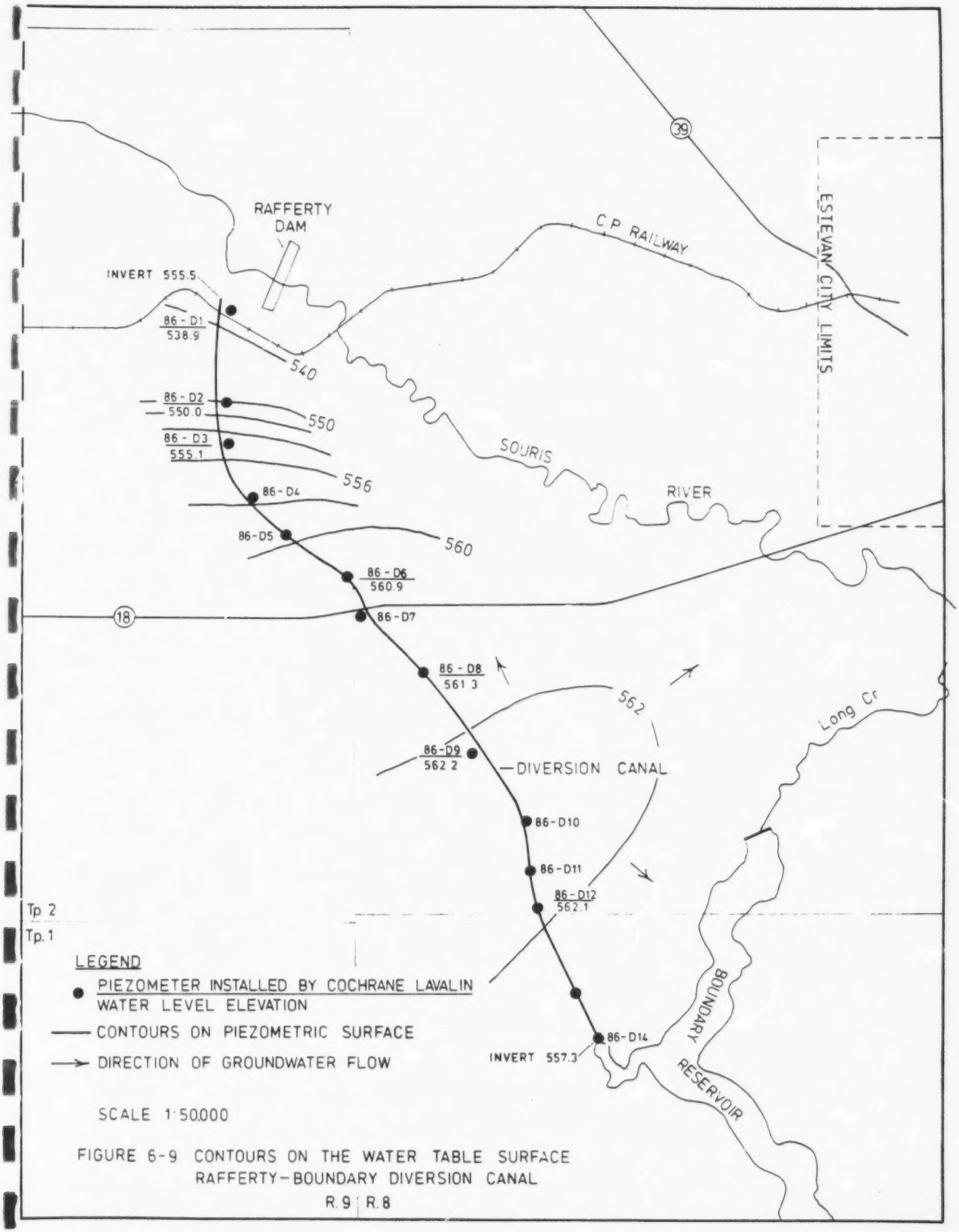


FIGURE 6-9 CONTOURS ON THE WATER TABLE SURFACE
RAFFERTY–BOUNDARY DIVERSION CANAL

between drift groundwater quality and depth. Drift aquifers were separated into three depth ranges: 0-18m (0-60 ft.), 18-61m (60-200 ft.), and greater than 61m (200 ft.). The results of analyses on water from these depths is shown in Table 6-1. Drift aquifers 0-18m deep yield calcium, magnesium, sodium-sulphate, and bicarbonate-type water. This water is of poor quality, is very hard, and has high concentrations of sulphate, iron, manganese and TDS.

Drift aquifers 18-61m deep also yield calcium, magnesium, sodium-sulphate, bicarbonate-type water. This water is also of poor quality and has high concentrations of sulphate,not recommended for consumption and is moderately alkaline. Drift aquifers greater than 61m deep yield waters of the sodium-sulphate bicarbonate type. This water is of poor quality and has high concentrations of iron, manganese, TDS, is hard, has concentrations of sulphate not recommended for consumption and is moderately alkaline.

Changes in the chemistry of drift groundwater occur as the groundwater moves downward through the drift. The groundwater changes from a calcium, magnesium, sodium-sulphate bicarbonate water to a sodium-sulphate bicarbonate water. This transition is illustrated in a Piper plot (Hem 1970) shown in Figure 6-10. The metamorphosis of the groundwater is due to base exchange reactions between clay minerals in the tills and the groundwater along its flow path.

The groundwater from the Estevan valley aquifer is one of the sodium bicarbonate type. Analyses of water sampled from this aquifer are given in Table 6-2. It is mineralized but less so than the other two major aquifers (Weyburn Valley and Ravenscrag Formation). Concentrations of iron, manganese, TDS and alkalinity are however, considered undesirable. The Macoun site (Beckie, 1985) has somewhat more mineralized water than at the Souris well site. The sulphate concentrations are notably high in the results obtained by Puodziunas (1977) compared with a virtual absence of sulphate in water pumped from the Souris and Macoun wells.

Groundwater from the Weyburn valley aquifer is of the sodium-bicarbonate, chloride, sulphate type. It is similar to, but more mineralized than, water in the Estevan aquifer. Examples of water sampled from this aquifer are given in Table 6-2. These differences can be accounted for by an increase in the proportion of sodium, chloride and sulphate ions. An examination of Figure 6-10 shows that the quality in the aquifer becomes closer to a sodium chloride type as Weyburn is approached. This condition probably reflects the contribution of saline groundwater from the Riding Mountain Formation lying north of Township 4.

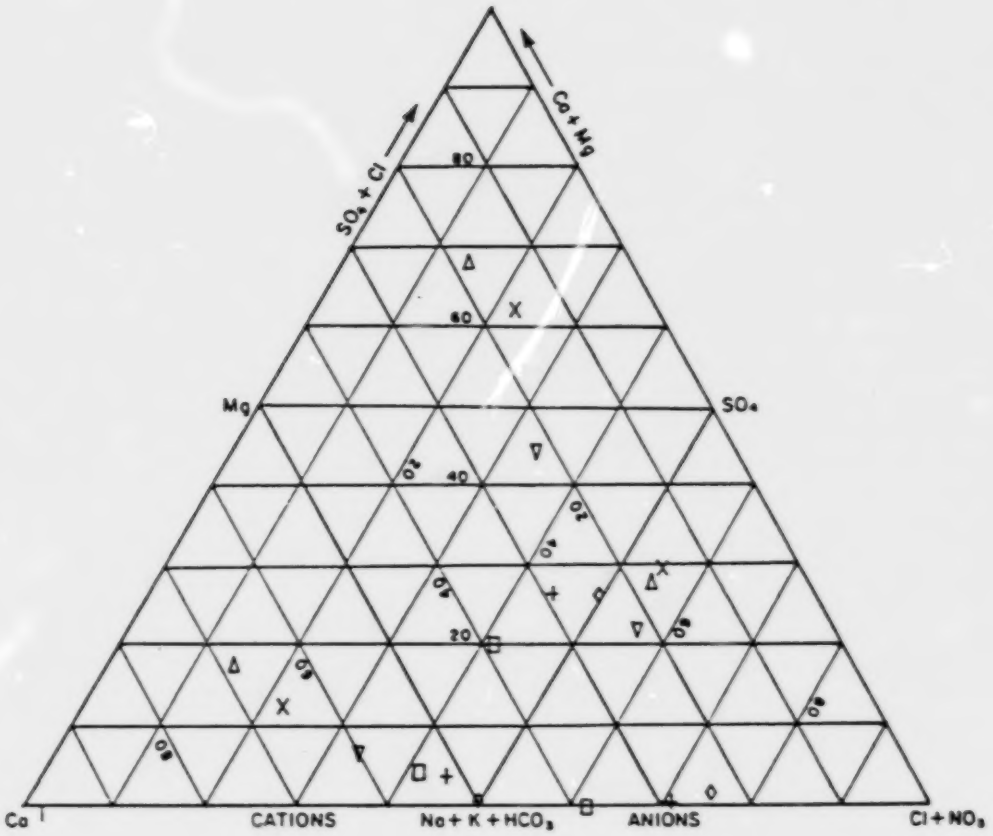
Groundwater from the Ravenscrag Formation aquifer is of the sodium-bicarbonate chloride type (Figure 6-10). The groundwater is highly mineralized with a TDS of approximately 2500mg/L as may

TABLE 6-1
Groundwater Quality of Drift Aquifers

	Drift Aquifers 0 to 18 m n=21		Drift Aquifers 18- 61 m n=20		Drift Aquifers deeper than 61 m n=8	
Constituent	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Bicarbonate	478	128.9	704	245.4	880	424.3
Sulphate	724	789.8	1280	980.3	833	582.9
Chloride	51	46.7	97	91.9	121	161.4
Calcium	201	111	285	136.1	168	166.5
Magnesium	111	87.6	128	70.7	58.3	59.8
Sodium	129	142.3	373	257	511	309.6
Potassium	10.1	7.62	10.85	5.26	11.0	4.4
Iron	4.33	13.46	7.8	9.17	6.1	6.16
Manganese	0.52	0.68	1.12	1.63	0.68	0.91
TDS	1749	1143	2918	1330	2584	1104
Conductivity	1664	1129	3106	1481	2758	967
Total Hardness	980	818.6	1240	576	655	659
Total Alkalinity	391	105.6	590	204	721	348

SOURCE: Pupacliunas (1977)

Notes: 1. All values are reported as mg/l except conductivity which is in micro mho/cm
2. Analyses are reported as the mean value of n analyses.



Legend

△	D(0-18)	Drift Aquifers, 0-18m, mean of 31 samples (Puodziunas, 1977)
X	D(18-61)	Drift Aquifers, 18-61m, mean of 20 samples (Puodziunas, 1977)
▽	D(61)	Drift Aquifers, >61m, mean of 8 samples (Puodziunas, 1977)
□	PW2UL	Souris site pump well, sampled 09/17/84 (Beckie 1984)
+	W2	City of Weyburn well, sampled 23/10/73 (SRC analysis)
◊	R-P	Ravenscrag Formation Aquifer, mean of 22 samples (Puodziunas, 1977)

FIGURE 6-10

RAFFERTY RESERVOIR
PIPER PLOT OF GROUNDWATER CHEMISTRY

SOURCE : SASKMONT ENGINEERING

TABLE 5-2

Groundwater Quality of Buried Valley and Ravenscrag Aquifers

	Estevan Valley Aquifer				Weyburn Valley Aquifer				Ravenscrag Formation Aquifer			
	Puodziunas1		Souris Well2	Macoun Well3	Puodziunas 4		Texaco5	Weyburn Well6	Puodziunas 7		Meneley 8	
Constituent	Mean	SD	PW2UL		Mean	SD			Mean	SD	Mean	SD
Bicarbonate	947	193.7	965	845	768	192	1093	575	960	450.9	999	309
Sulphate	214	322.5	0.1a	1a	384	323.6	27	537	66	128.3	157	360
Chloride	146	82	177	314	444	219.6	500	464	628	620.8	608	551
Calcium	88	43.6	52	39	78	60.8	43	46	19.3	21.4	14	9
Magnesium	33	18.5	23	18	29	24	30	17	6.9	8.7	7	7
Sodium	385	158.8	386	413	622	172.1	618	740	768	380.2	820	275
Potassium	8.4	2.6	5.6	8.2	6.4	3.21	7	4	4.9	3.7	2	3
Iron	6.6	6.2	3.2	3.0	2.9	3.64	2.33	7	2.6	2.6	-	-
Manganese	0.15	0.09	0.048	0.076	0.17	0.13	-	4	0.04	0.06	-	-
TDS	1853	527.7	1590	1640	2346	599	2316	2494	2470	948	2619	682
Conductivity	2006	581	1860	1980	2996	762	2640	3230	3183	1613	3417	1497
Total Hardness	419	314.9	225	172	315	249.3	229	183	76	89.2	63	42
Total Alkalinity	757	201.6	791	692	634	181.7	896	553	799	322.9	-	-

Note:

All values are reported as mg/l except conductivity which is micro mhos/cm.

(a) indicates less than.

1) Data (mean of 22 samples) from Puodziunas (1977).

2) PW2UL well at Souris site, NW14-11-3-18-W2. Beckie (1984). Water sampled on 09/17/84 except for iron and maganese (sampled on 09/28/84)

3) Well at Macoun site, SW5-4-9-W2 (Beckie, 1983). Water sampled on 16/11/82.

4) Puodziunas (1977), mean of 7 samples.

5) Texaco Flowing Shothole, 500 gpm, 59.4 m deep, NE24-4-12-W2, 9 Mar. 1966.

6) Weyburn Well, 71.6 m deep, SW17-8-14-W2.

7) Puodziunas (1977), mean of 22 samples.

8) Menely (1983), mean of 64 samples except for Mg=63 samples, K=52 samples and Conductivity=21 samples

be seen in Table 6-2. Several constituents are at elevated concentrations making water quality poor for private water supplies.

.2 Major Ion Chemistry

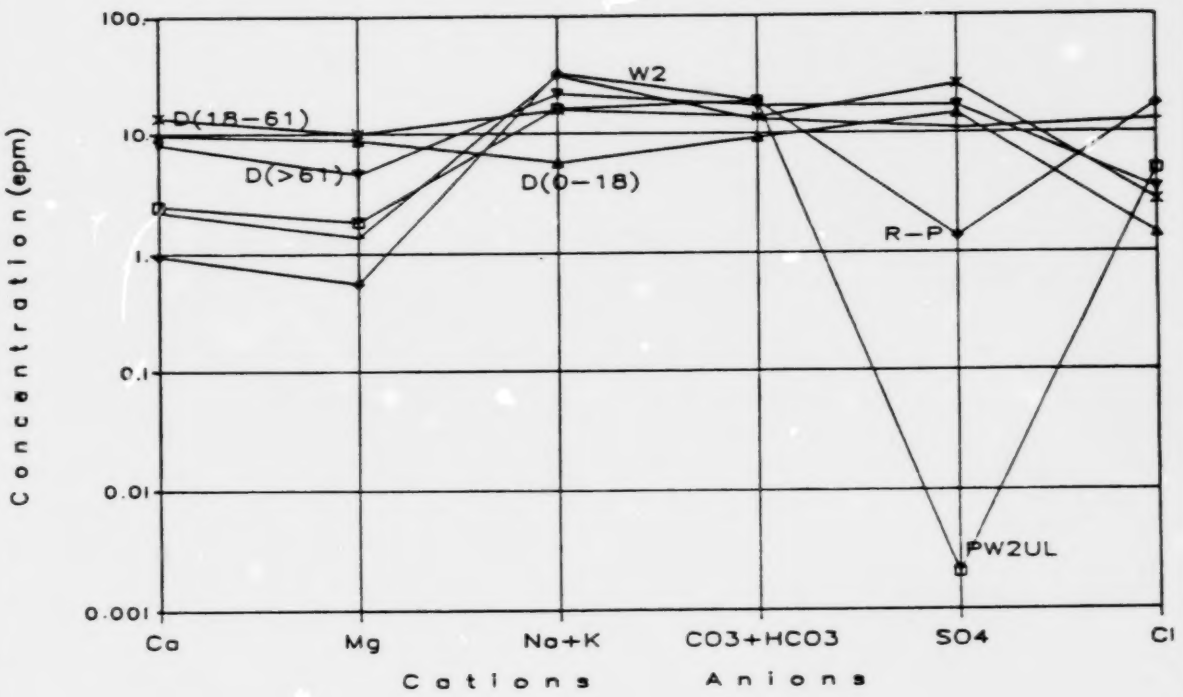
Selected water quality data on samples collected from the Estevan, Weyburn and Ravenscrag aquifers and averaged water quality data from the drift were converted to equivalents per million (epm) and applied to Schoeller (1955) graphic analysis in Figure 6-11. The Schoeller diagram allows the chemical data to be characterized in terms of the concentrations of cations or anions in a convenient manner for visual inspection .

An examination of Figure 6-11 shows the Ravenscrag Formation aquifer is characterized by low concentrations of calcium and magnesium and high concentrations of chloride relative to the drift and other aquifers. Drift groundwaters are best characterized by low concentrations of chloride relative to other aquifers . In addition, shallow drift (Ø-18m) shows lower concentrations of bicarbonate, sodium and potassium than do the principal aquifers. The Estevan aquifer is characterized by low concentrations of sulphate. The Weyburn aquifer has no characteristic features as it is a mixture of groundwaters.

637 WATER USE

An inventory of existing water wells in a portion of the study area was made. The area in the vicinity of the Rafferty reservoir and Shand site was inventoried separately from the Alameda reservoir area. The inventories were made using water well records from Saskatchewan Water Corporation. One of the areas inventoried (Figure 6-12) was restricted to the Rafferty Reservoir at 555m elevation, the area above the buried Estevan and Weyburn aquifers, and the Shand site. The other inventoried area was restricted to the Alameda reservoir. In addition to these areas, the inventories were extended a minimum of 1.6 km. The locations of inventoried wells for Rafferty/Shand and Alameda are shown on Figures 6-12 and 6-13 and a summary of the well records used in the inventories is given in Appendix A. Tables 6-3 and 6-4 summarize water use based on these inventories.

In the Rafferty/Shand area the Drift is the most frequently used aquifer (Table 6-3). No wells are shown to be completed in the Estevan Valley and Weyburn Valley aquifers per se. A number of wells noted as completed in "glacial" deposits will actually be completed in the Estevan or Weyburn Valley aquifers. It is interesting to note that the highest capacity and deepest wells are completed in the Blairmore Formation. This formation is used as a source for oilfield waterflood purposes. Farm wells which supply domestic and stock watering needs are the most common type of wells in the area.



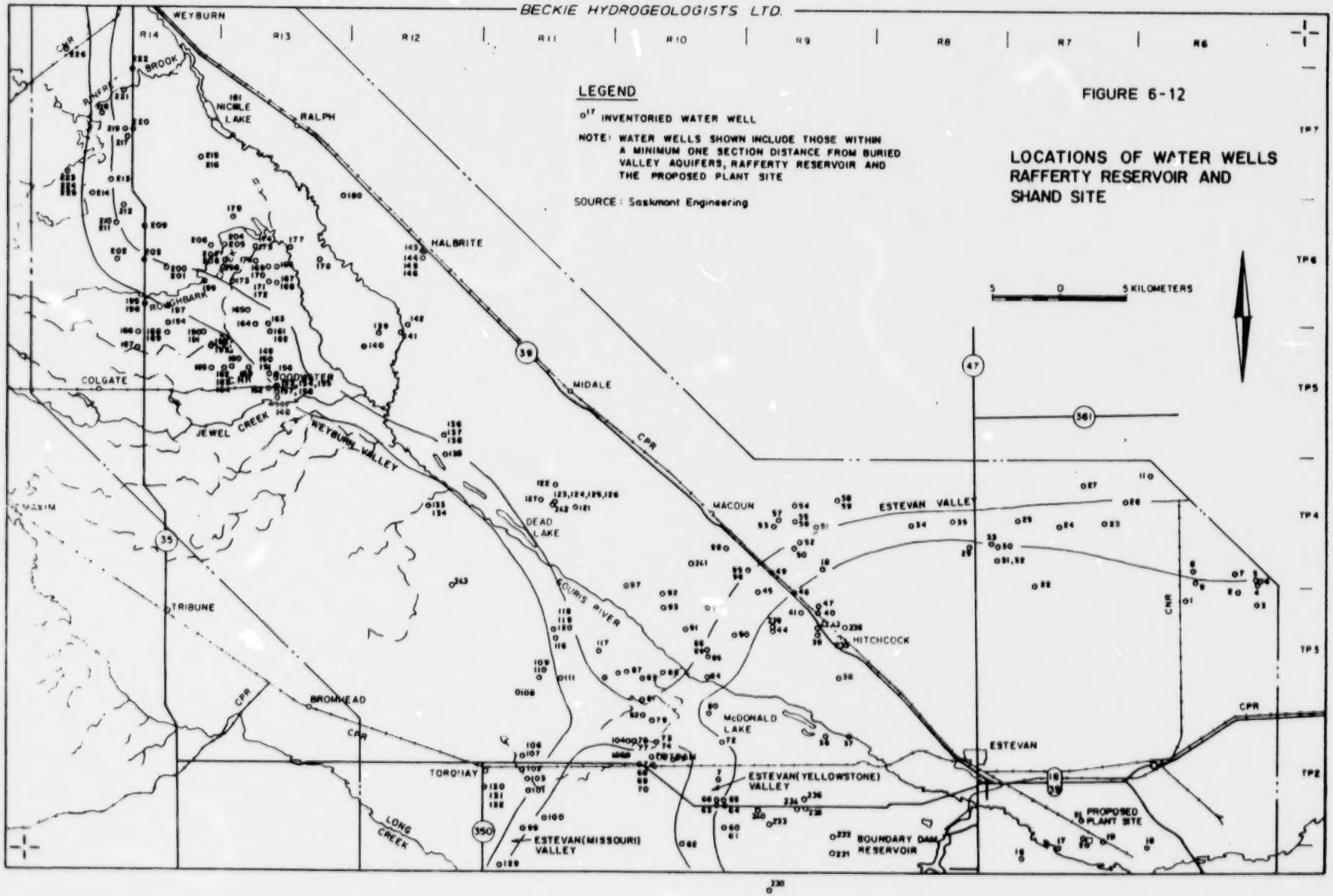
Legend

△	D(0-18)	Drift Aquifers, 0-18m, mean of 31 samples (Puodziunas, 1977)
x	D(18-61)	Drift Aquifers, 18-61m, mean of 20 samples (Puodziunas, 1977)
▽	D(61)	Drift Aquifers, >61m, mean of 8 samples (Puodziunas, 1977)
□	PW2UL	Souris site pump well, sampled 09/17/84 (Beckie 1984)
+	W2	City of Weyburn well, sampled 23/10/73 (SRC analysis)
◇	R-P	Ravenscrag Formation Aquifer, mean of 22 samples (Puodziunas, 1977)

FIGURE 6-11

RAFFERTY RESERVOIR
SCHOELLER DIAGRAM OF
GROUNDWATER CHEMISTRY

SOURCE : SASKMONT ENGINEERING


BECKIE HYDROGEOLOGISTS LTD.
LEGEND
INVENTORIED WATER WELL
NOTE: WATER WELLS SHOWN INCLUDE THOSE WITHIN A MINIMUM ONE SECTION DISTANCE FROM BURIED VALLEY AQUIFERS, RAFFERTY RESERVOIR AND THE PROPOSED PLANT SITE
SOURCE: Saskmont Engineering
FIGURE 6-12
LOCATIONS OF WATER WELLS RAFFERTY RESERVOIR AND SHAND SITE
5 0 5 KILOMETERS
WEYBURN
R14
R13
R12
R11
R10
R9
R8
R7
R6
TP7
TP6
TP5
TP4
TP3
TP2
RALPH
NICOLE LAKE
HALBRITE
ROCHAMBARK
COLGATE
MIDALE
JEWEL CREEK
WEYBURN VALLEY
MACOUN
ESTEVAN VALLEY
DEAD LAKE
MAXIM
TRIBUNE
SOURIS RIVER
HITCHCOCK
BROMHEAD
McDONALD LAKE
ESTEVAN
TORQUAY
ESTEVAN(YELLOWSTONE) VALLEY
ESTEVAN(MISSOURI) VALLEY
LONG CREEK
PROPOSED PLANT SITE
BOUNDARY DAM RESERVOIR
CPR
CNR
39
47
361
35
350
18

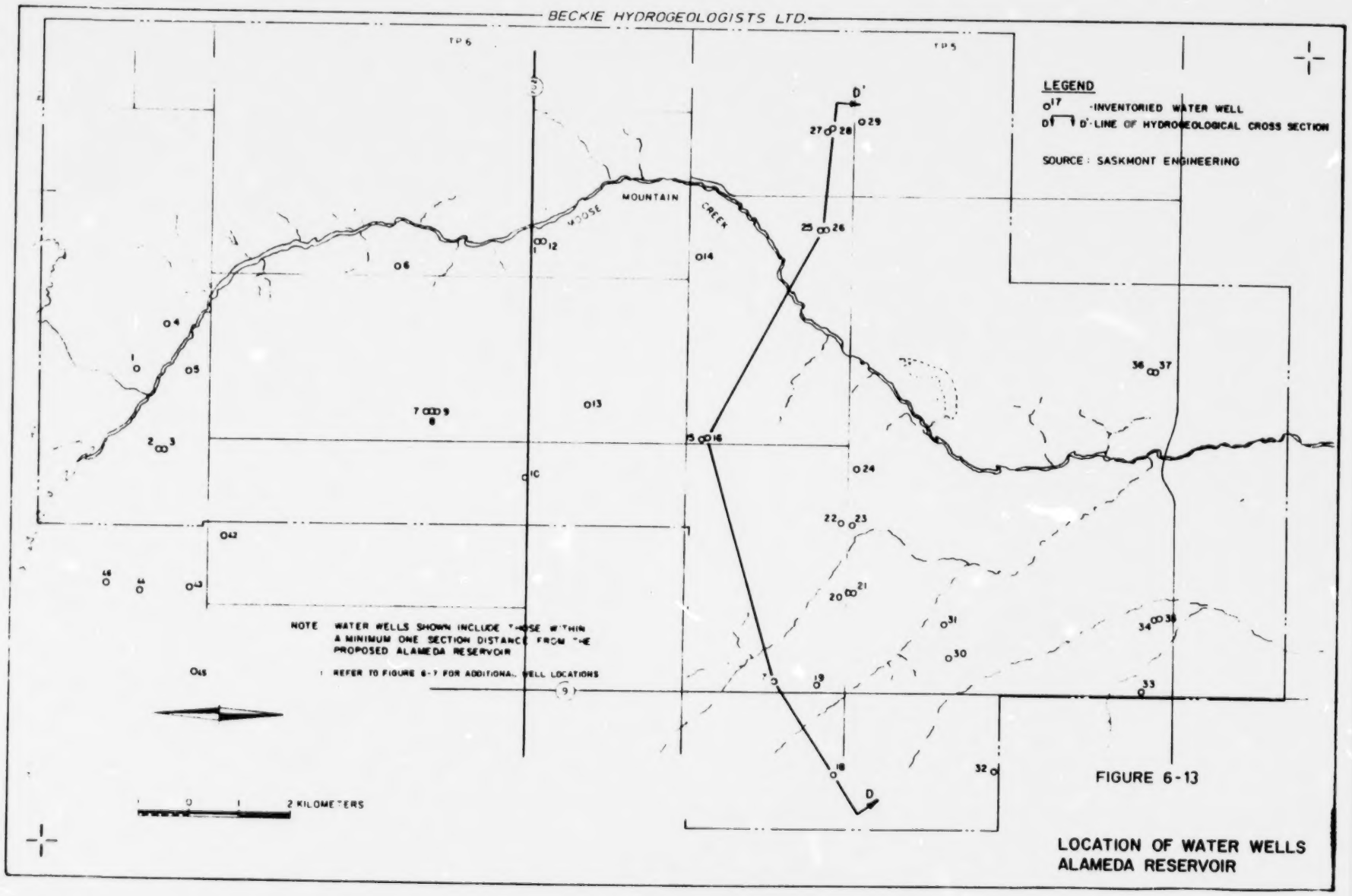

BECKIE HYDROGEOLOGISTS LTD.
TP 6
TP 5
LEGEND
-INVENTORIED WATER WELL
D D'-LINE OF HYDROGEOLOGICAL CROSS SECTION
SOURCE : SASKMONT ENGINEERING
MOOSE MOUNTAIN CREEK
NOTE WATER WELLS SHOWN INCLUDE THOSE WITHIN A MINIMUM ONE SECTION DISTANCE FROM THE PROPOSED ALAMEDA RESERVOIR
1 REFER TO FIGURE 6-7 FOR ADDITIONAL WELL LOCATIONS
0 1 2 KILOMETERS
FIGURE 6-13
LOCATION OF WATER WELLS
ALAMEDA RESERVOIR

TABLE 6-3
Water Use and Generalized Aquifer Characteristics1
Rafferty Reservoir/Shand Site

Aquifers	Number of Wells	Percent of Inventoried Wells	Depth (m) Mean	Depth (m) SD	Yield (L/s) Mean	Yield (L/s) SD
Drift	180	80	33.6	35.1	0.6	1.0
Ravenscrag Formation	26	11	73.8	38.1	0.6	0.7
Blairmore Formation	10	4	1103	87	23.0	8.9

Notes:

1) Well records do not distinguish those wells constructed in the Estevan valley and Weyburn valley aquifers
2) Completion of a water well in a particular aquifer does not necessarily indicate it is in use.

TABLE 6-4

Water Use and Generalized Aquifer Characteristics
Alameda Reservoir Area

Aquifers	Number of Wells	Percent of Inventoried	Depth (m) Mean	Depth (m) SD	Yield (L/s) Mean	Yield (L/s) SD
Drift	15	38	34.2	32.3	0.3	0.3
Ravenscrag Formation	24	62	95.0	18.6	0.3	0.2

Note:

1) Completion of a water well in a particular aquifer does not necessarily indicate it is in use.

6.4 IMPACT ON EXISTING HYDROGEOLOGICAL ENVIRONMENT

The construction of the Rafferty and Alameda reservoirs will have a significant impact upon the groundwater regime, but except for increased groundwater discharge below the dams, which could lead to higher soil salinity, the groundwater resources will benefit from the creation of these reservoirs.

Since the Rafferty reservoir is much longer, and overlies major aquifers at relatively shallow depths, the impact on the groundwater resources in the area will be much greater than the impact imposed by the Alameda reservoir.

641 Rafferty Reservoir

The proposed Rafferty reservoir will affect the groundwater regime of two major, regional aquifers of the study area and will also affect numerous smaller but equally important aquifers.

.1 Estevan Valley Buried Valley Aquifer System

Because of the reduction in thickness of the confining layer, the Souris Valley presents the most likely area for surface water - groundwater interactions to occur within the groundwater flow regime of the Estevan Buried Valley Aquifer System . But even with the new hydraulic head conditions that will be imposed by the Rafferty reservoir, the change in the flow system of this aquifer will not be significant.

Based on present head differentials a vertical hydraulic conductivity of 4.8×10^{-4} m/day (Walton, 1970), a 40 metre thick confining layer and the modified Darcy Flow Equation (see appendix B), the Estevan Valley aquifer is estimated to be discharging into the Souris Valley at a very low rate of 3.26 lps in the vicinity of the Souris River Pumpwell site (see Figure 1). With the Rafferty at a FSL of 549.5 the driving hydraulic head will be reduced to about 8.5 metres. Again using the modified Darcy Flow Equation the discharge rate of the Estevan Valley Aquifer at this rate will be reduced to less than 1.0 lps. In an aquifer of this size and permeability, this change in discharge will have very little effect on the net flow system.

Similarily using present head differentials a vertical hydraulic conductivity of 4.8×10^{-4} m/day, a 50 metre thick confining layer and using the modified Darcy Flow Equation, as outlined above, the Weyburn Channel aquifer discharge into the Souris Valley at a rate of about 8.51 lps along the 9 kilometer stretch of aquifer overlain by the Rafferty reservoir. With the Rafferty FSL this discharge would decline to 7.02 lps.

.11 Development of the Estevan Valley Aquifer System. The Saskatchewan Power Corporation is considering development of the

Estevan Valley Aquifer to supplement Boundary Dam Lake during periods of low runoff. This development, if approved, will be located in the Estevan Valley Aquifer adjacent to the Souris Valley. It has been predicted (SRC, 1985) that long term drawdown in the Estevan Valley Aquifer at the Souris River Pumpwell site will be in the order of 50 metres at a production rate of 6100 dam^3/year.

The proposed development of the Estevan Valley Aquifer will reduce the hydraulic pressure such that there will then be a net inflow downward from the Souris Valley. Using the same principles to calculate aquifer discharge, the amount induced recharge can be estimated. With a drawdown estimated to be about 50 metres (SRC, 1985) and assuming a constant reservoir level of 549.5 m, total induced recharge using the modified Darcy flow equation and, will be less than 6.0 lps (190 Dam^3/year) at the Souris River Pumpwell site. This represents only 3% of the total projected pumping rate (6100 Dam^3/year).

Because of the depth of the Estevan Valley Aquifer and the relatively small area of interaction, the Rafferty reservoir is not expected to have much influence on the flow system of the aquifer in this area.

Where the proposed Rafferty reservoir crosses the Weyburn Channel, because of the much larger area of potential interaction the interactions between groundwater and surface water will be more significant should development of the Estevan Valley Aquifer proceed. If drawdown in this leg of the aquifer is about 30 metres (SRC, 1985) and the average head imposed by the Rafferty reservoir is about 10 metres then the total induced flow into the Weyburn Channel along this 9 kilometer stretch will be in the order of 11 lps or about 330 dam^3/year. This represents about 5% of the annual proposed pumping rate and as a result could moderately reduce long term drawdown in that area.

.2 Drift Aquifers

Because of the great distance over which potential surface water interactions may take place, there is little doubt that numerous drift aquifers will be affected by the proposed Rafferty reservoir. Except possibly for the Tableland aquifer, most of these aquifers are relatively small and isolated, and therefore it is difficult to predict what impact the Rafferty reservoir might have based on the existing hydrogeological data. The Tableland Aquifer, on the other hand, is an extensive drift aquifer which may be significantly affected by the Rafferty Reservoir.

As discussed earlier, the Tableland aquifer may be intersected by the Souris Valley in the vicinity of Lake McDonald. In order to estimate what effect the Rafferty Reservoir may have on this aquifer and other drift aquifers along the length of the proposed reservoir, a simple line sink model was

prepared. The model incorporates an analytical algorithm (see Appendix B) to predict inflows and head buildup in a confined, isotropic homogeneous aquifer of infinite extent. The model also assumes constant head in the reservoir and gives no consideration to the likelihood of a low permeability "skin" of aluvium covering the aquifer at the line sink.

Assuming an aquifer width of 1600 metres, a coefficient of transmissivity of 3.73×10^{2} m^2/day and a storage coefficient of 2.4×10^{-4} the inflow to this aquifer would be below 1×10^{4} m^3/day 100 days after a instantaneous FSL of 549.5 had been reached (see Figure 6-14). Initial flow into the aquifer may be as high as 2 to 3×10^{4} m^3/day.

The model also predicts that the hydraulic head in the aquifer could be increased up to a distance of over 30 kilometers from the proposed Rafferty reservoir (see Figure 6-15). The net change in the flow regime of the Tableland Aquifer will be decreased in the amount of discharge to the Souris Valley. The head increase is insufficient to change flow directions.

Based on the above calculations, the Tableland Aquifer, and for that matter, other drift aquifer with similar hydraulic characteristics, could interact with the Rafferty reservoir in a very significant way. It is theoretically possible that the Tableland Aquifer could drain the Rafferty reservoir at a rate of about 3600 Dam^3/year. However, within the scope of this evaluation all drift aquifers in contact with the Rafferty reservoir are finite in extent and as a result will drain the reservoir only during initial filling to a maximum governed by their storage capabilities.

The interaction between drift aquifers and the Rafferty reservoir will be beneficial to both the groundwater resources of the area and also the actual storage potential of the reservoir. Water level increases in drift aquifers adjacent to the reservoir will provide for higher well yields and decreased pumping costs. With regard to the total storage capacity of the reservoir, the drift aquifers will provide bank storage and in the case of the Tableland Aquifer, this may be a significant volume.

.3 Ravenscrag Aquifer

Because the Ravenscrag Aquifer lies beneath the entire bottom half of the proposed Rafferty reservoir, it may be expected to receive the greatest hydrogeological impact of all aquifers interacting with this project. However, because of the low hydraulic conductivity (vertical and horizontal) found in this aquifer, the affect of the Rafferty reservoir will not be nearly as significant in terms of surface water discharge and extent of water pressure buildup as that which has been estimated for drift aquifers.

The analytical algorithm (see Appendix B) was again used to

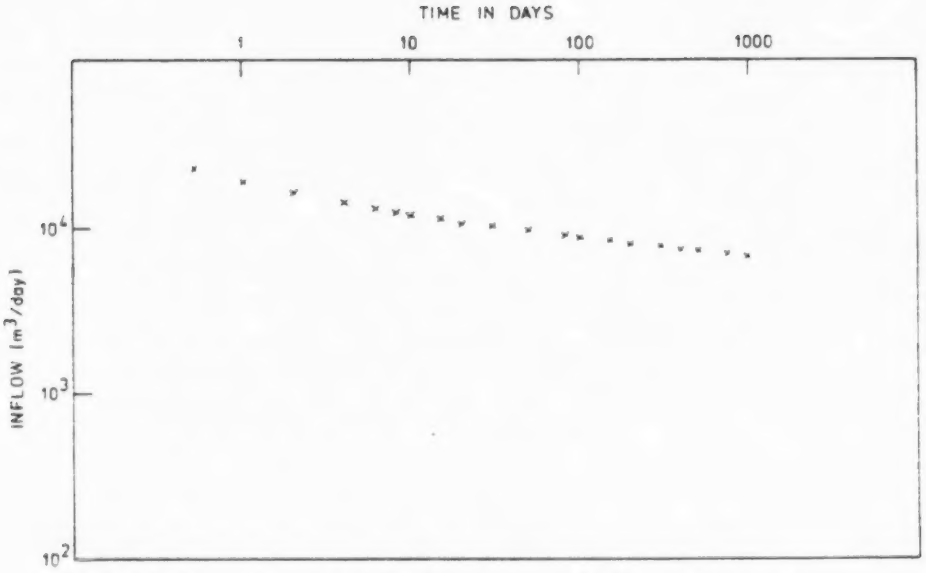


FIGURE 6-14 Simulated Discharge from Rafferty Reservoir into Tableland Aquifer

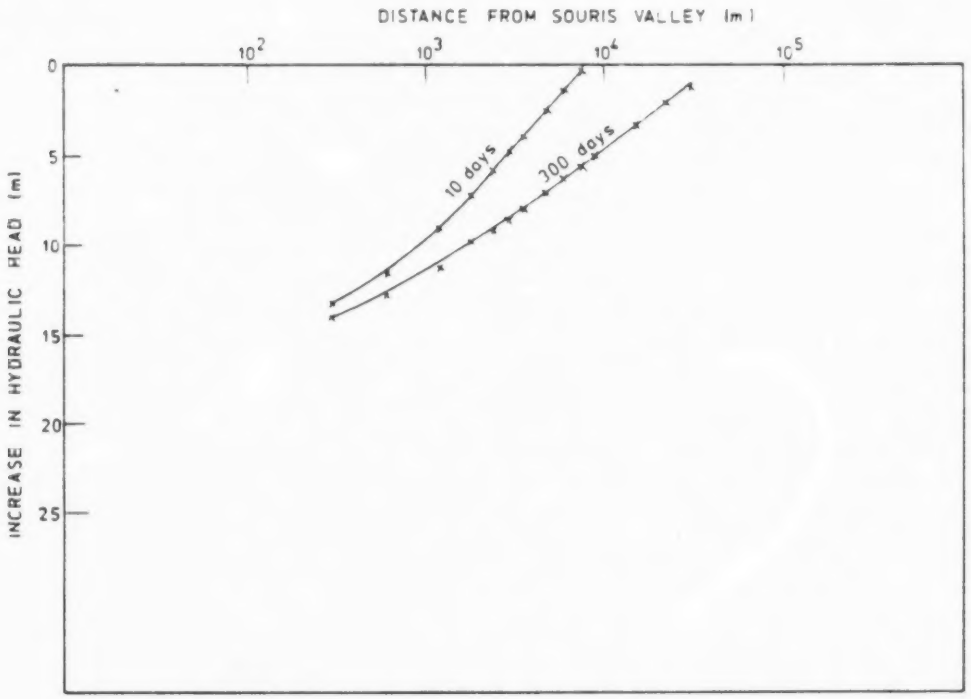


FIGURE 6-15 Simulated Head Buildup in the Tableland Aquifer

develop a simple line sink model to estimate what impact the Rafferty reservoir would have on the Ravenscrag aquifer. To estimate the maximum surface water - groundwater interaction, the model simulates a 10 kilometer length of the proposed reservoir immediately above the dam where surface water head would be the greatest and also where the Souris Valley actually cuts into the Ravenscrag aquifer. The model assumes the Souris Valley aluvium has the same hydraulic characteristics as the Ravenscrag aquifer and therefore will not impede or enhance surface leakage.

With an estimated transmissivity of 20 m^2/day, a storage coefficient of 1.0×10^{-3} and a reservoir level of 550.0 MASL the model simulation predicts initial (1 - 2 days) leakage from the reservoir may exceed 2×10^4 m^3/day, but will rapidly decline to less than 3.0×10^3 m^3/day between 100 and 300 days after the reservoir has been filled (see Figure 6-16).

The model also predicts that after 300 days with the reservoir at a constant level of 550.5 MASL, hydraulic head buildup in the Ravenscrag Aquifer will not spread more than 10 kilometers from the reservoir (see Figure 6-17 and 6-18). The actual radius of influence will be much less because of the internal lensing which is characteristic of this aquifer. Upstream of the area where the model simulation was applied, head build up in the Ravenscrag will be much less as there is a till separation which thickens in that direction.

The hydraulic head increase in the Ravenscrag Aquifer caused by the proposed Rafferty reservoir will improve the groundwater resources in a similar manner that was predicted for drift aquifers. But because of the low hydraulic conductivity of this aquifer these benefits may take several years to occur. For the same reason, very little consideration should be given to the volume of bank storage this aquifer may provide in calculating total reservoir capacity.

.4 Seepage Through Souris Valley Aluvium

The seepage that may take place through the Souris Valley aluvium beneath the proposed Rafferty dam can be estimated using the modified Darcy flow equations (see appendix B).

Assuming a flow path beneath the Dam of about 300m, a cross sectional flow area of about 1400 m^2 and a hydraulic conductivity for a clay-silt of 0.01 m/day (Walton, 1970) then the flow rate would only amount to about 9 m^3/day. Unless the basal gravels and other permeable deposits in the aluvium prove to be more extensive then it is not likely that significant flow rates will take place through the Souris Valley aluvium.

.5 Groundwater Discharge and Soil Salinity Below the Rafferty Dam

With an increase in hydraulic head in the Ravenscrag Aquifer

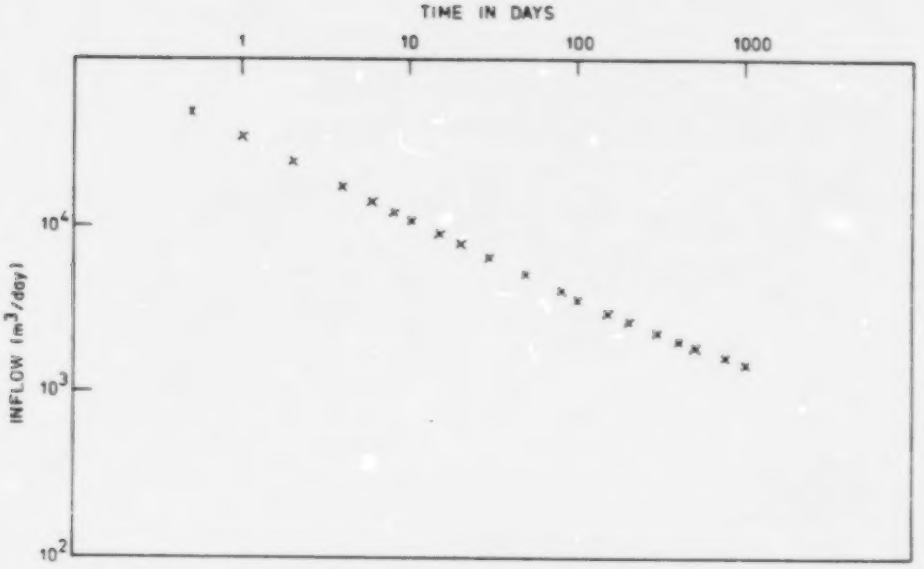


FIGURE 6-16 Simulated Discharge from Rafferty Reservoir into Ravenscrag Aquifer

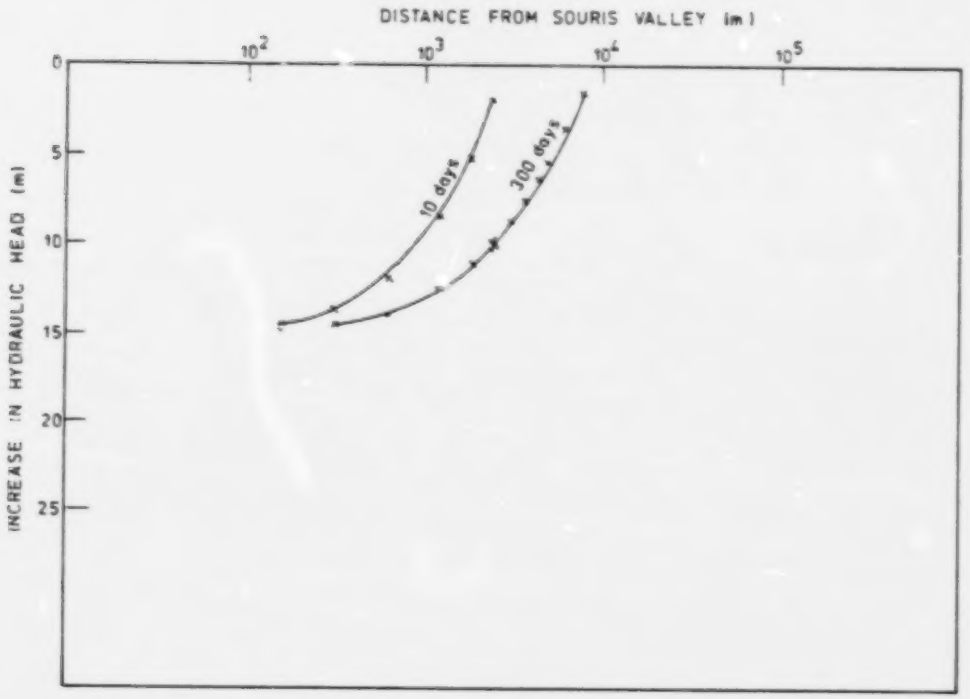
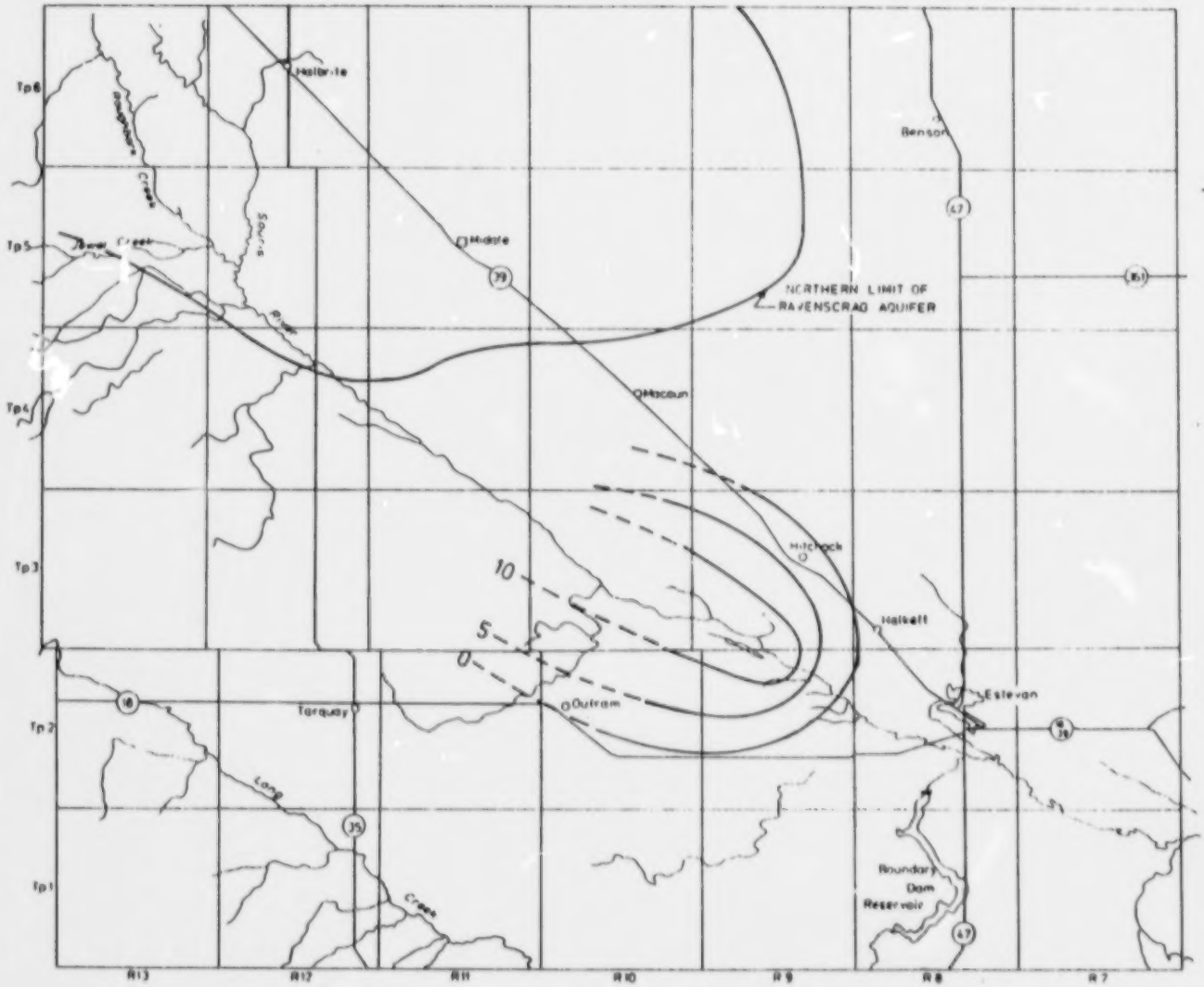


FIGURE 6-17 Simulated Head Buildup in the Ravenscrag Aquifer



LEGEND

---— CONTOURS ON THE CONE OF IMPRESSION

10 0 10 kilometers

FIGURE 6-18

SIMULATED WATER LEVEL BUILDUP
RAVENSCRAG AQUIFER
300 DAYS FSL OPERATION

RAFFERTY RESERVOIR

BECKIE HYDROGEOLOGISTS LTD.

below the proposed Rafferty Dam (see Figure 6-18) there will be an increased rate of groundwater discharge. Subsequently, there may be an increase in soil salinity if this additional volume cannot be dissipated laterally through the aluvium.

Based on the model prepared to estimate the surface water-groundwater interactions in the Ravenscrag formation it can be seen that the hydraulic head in the aquifer will increase up to a distance of 2100 metres below the proposed damsite. At an average head of 7 metres, a discharge area of 1.4 x $10^6 m^2$, and a vertical hydraulic conductivity of 1 x 10^{-3} m/day (IJC, 1979) the total increase in groundwater discharge could amount to 4.9 x $10^2 m^3$/day.

Although the increase in groundwater discharge calculated above is not overly significant, if the aluvium cannot transmit this flow downstream, then soil salinity may increase over much of the area below the dam up to a distance which may exceed 2 kilometers. Basal sand and gravel deposits and other pervious layers in the alluvium could be used to reduce the fluid pressure if they can be pumped from.

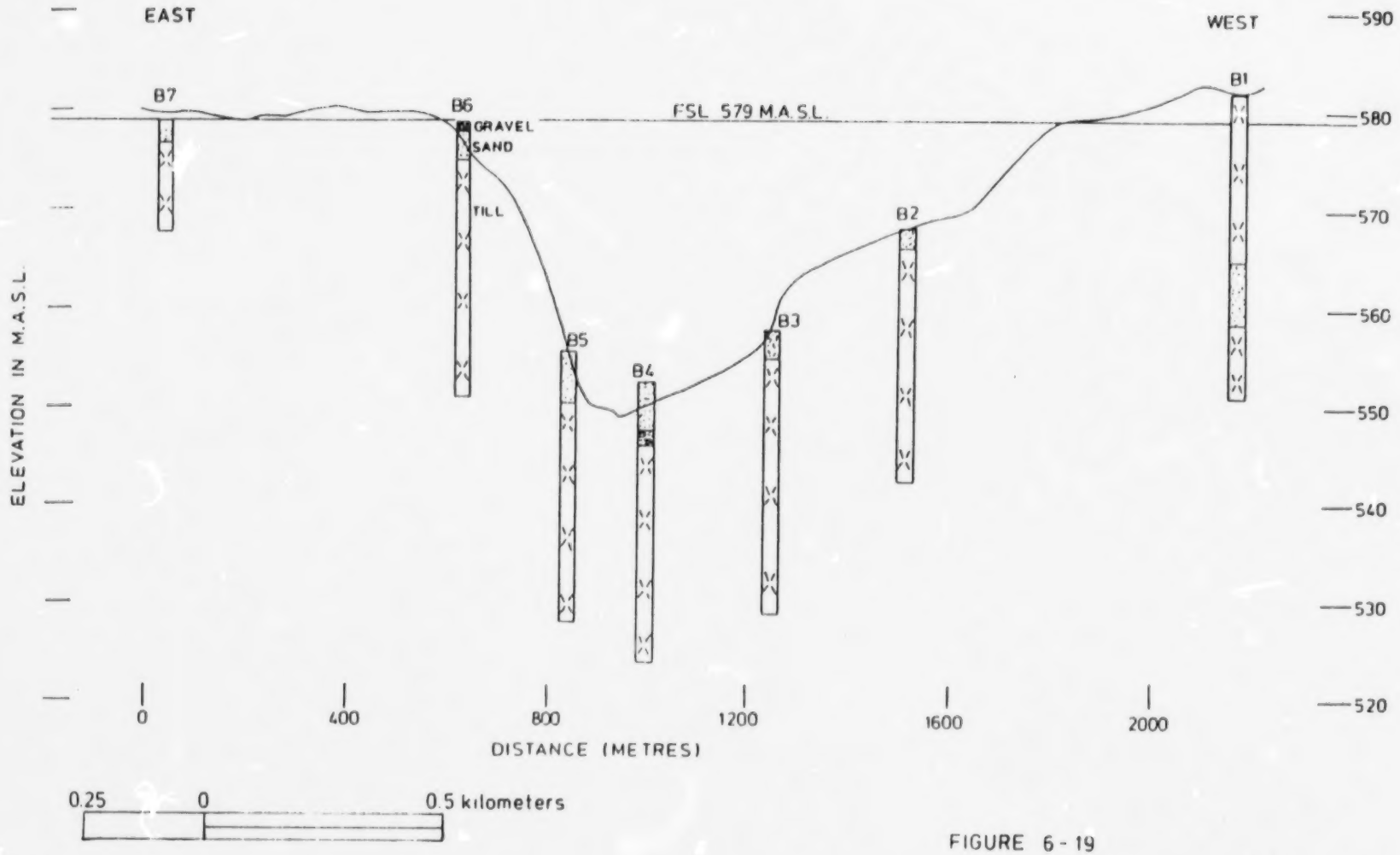
642 ALAMEDA RESERVOIR

Although the proposed Alameda reservoir will be about 20 kilometers long and will be about 30 metres deep at the dam, the hydrogeological impact of this project will not be nearly as significant as the impact predicted for the proposed Rafferty reservoir.

Even though the Ravenscrag Aquifer underlies all of the area to be flooded by the proposed Alameda Reservoir, its depth is a limiting factor against potential surface water interactions. At the site of the proposed dam the Ravenscrag Formation is separated from the reservoir bottom by up to 50 metres of till. This till separation increases to almost 60 metres at the headwaters of the Reservoir. Assuming a vertical hydraulic conductivity of 3.5 x 10^{-5} (IJC,1979) a seepage area of 1.25 x 10^7 m^2 and a average hydraulic head of 15 metres, the total estimated seepage into the Ravenscrag Aquifer would be only 119 m^3/day. it is without question that such a low seepage rate over an area of this size would not have a noticeable impact on the flow system of the Ravenscrag Aquifer.

Major intertill and subtill aquifers are not evident in the area of the Alameda reservoir so that the impact of the reservoir can not be fully estimated on this group of aquifers. It can be said that the groundwater resources of any smaller, isolated drift aquifers will benefit from the new source of recharge or decrease in present discharge.

The surficial drift occurring mainly on the east flank of the proposed Alameda reservoir (see Figure 6-19) is most likely



SOURCE : Cochrane Lavalin Inc.
Note figure 6-8 for cross-section location

FIGURE 6-19

ALAMEDA RESERVOIR

GEOLOGIC CROSS-SECTION E-E′

BECKIE HYDROGEOLOGISTS LTD.

unsaturated and if below FSL it will benefit greatly from the new source of recharge provided by the reservoir. This particular deposit will provide some bank storage but because it is only about 5 metres thick and since it is surficial, this may not be a significant factor.

As noted on Figure 6-19, the floor and walls of the Moose Mountain Creek Valley are covered with a 3-6 metre thick blanket of sand and gravel. This deposit is probably a combination of valley aluvium and terrace and outwash deposits. This unit together with the surficial drift may provide a possible leakage path around and under the dam. At an average thickness of 4.2 metres, a cross-sectional flow area of 5.3 x 10^3 m^2, an assumed dam width of 300 metres and an estimated hydraulic conductivity of 10 m/day the leakage that may occur beneath the dam may be as high as 2.65 x 10^3 m^3/day.

If the aluvium below the proposed Alameda dam is as permeable as it appears to be at the damsite them an increase in soil salinity should not occur. Lateral flow in the aluvium will be controlled by the Moose Mountain Creek head which should effectively drain the area downstream of the dam.

643 RAFFERTY - BOUNDARY DIVERSION CHANNEL

A diversion channel to connect Boundary Dam Reservoir with the proposed Rafferty Reservoir is being considered. The channel would allow water from Boundary Reservoir to flow into the larger Rafferty Reservoir during excess flood periods and also would provide a return flow to maintain Boundary F.S.L. during dry periods.

Based on a geotechnical study carried out by Cochrane Lavalin in 1986, preliminary designs for the channel have been developed. The 9.6 kilometer long channel is to be in the order of 12 metres wide and will provide flows of up to 60 m^3/sec with a depth of water of 3.5 m. Although the proposed channel is generally less than 10m deep, groundwater levels are near surface and this project may have an impact on the local hydrogeological regime.

The degree of surface water-groundwater interaction that may occur as a result of excavating the diversion channel will depend upon the level of drainage allowed to occur in the channel during inactive periods. The worst situation would occur if control structures are left open and the channel is allowed to drain completely. The situation would lower the water table up to an average of 7 metres along a stretch from Boundary Dam Reservoir to the vicinity of 86-D5 (see figure 6-9). The proposed method of operation would be to keep the control structures closed and allow the channel to partially fill with groundwater. This would not only reduce the impact on the groundwater regime, it would also reduce losses to wetting of the channel each time it is

used.

The analytical algorithm (Appendix B) was also used to predict the effect of allowing groundwater to pond in the channel. With an annual evaporation rate of 50 to 75 cm/year, and assuming a median hydraulic conductivity for the Ravenscrag Aquifer of 8.75 x 10^{-1}m/day (Meneley, 1983), a channel length of 4.7km over which lowering of the water table will occur, it is predicted that the water table will decline in the order of 2.2 to 3.3 metres immediately adjacent to the channel with an effective radius of influence in the order of 200m. Water levels in the channel will remain at about 4 to 6 metres deep with evaporation losses in the order of 28.5 to 43.0 Dam^3/year.

The portion of the channel between 86-D5 and Rafferty Reservoir will be above the water table surface so that seepage losses can be expected. Assuming an operating water level of 3.5 metres the analytical algorithm predicts that the channel will lose up to 1.8 Dam^3 per week of flow.

The various surface water - groundwater interactions predicted to occur with the construction and operation the diversion channel, would appear to have little effect on the groundwater regime such that none of the relatively few wells in the area would be in risk. It is possible that some benefit may be provided by the channel as it may act as a drain of what appears (1:50,000 topographic map) to be fairly wet agricultural land.

644 CHANGES IN WATER CHEMISTRY

The bulk of the water contained within the proposed Rafferty and Alameda reservoirs will originate from spring runoff. These waters should be of superior quality compared to groundwater of the region and will improve the groundwater chemistry adjacent to the reservoirs in most cases.

During the initial stages of reservoir filling there will be a sudden reversal in groundwater flow. Salts which have accumulated in areas of groundwater discharge may be forced back into certain aquifers and depending on dilution factors and the character of the new groundwater flow system, there could be reduction in the quality of groundwater.

Flooding of farm land may result in flushing of various chemicals used in the farming practice so that some degree of contamination of groundwater may occur during initial filling. Complete filling of the reservoirs should dilute these potentially hazardous chemicals to concentrations below detection.

6.5 MONITORING AND REMEDIAL MEASURES

Because the proposed Rafferty and Alameda Reservoirs will benefit the groundwater resources as sites of new recharge, little monitoring will be required to watch for potential problems. The exceptions for each reservoir applies to the concern for leakage below and around the proposed dams and also the potential for increased soil salinity downstream from the dams.

The requirements for baseline data and ongoing monitoring together with estimated costs can be found in Appendix C.

651 Rafferty Reservoir

To observe the effects of the Rafferty Reservoir, monitors should be placed in the major aquifers. The Estevan Valley Aquifer has sufficient monitors at the souris Pumpwell site but the Weyburn Channel would require monitoring where it lies beneath the proposed reservoir. The upper granular sediments of the Ravenscrag Aquifer should be monitored in the area of highest expected head increase, that about midway between the Souris Pumpwell site and the dam. Seepage through the valley aluvium at the proposed Rafferty dam should not be significant, however, diversion of water through the Tableland Aquifer and soil salinity below the dam could be significant.

A test drilling and water level monitoring program should be carried out to determine the extent of the Tableland Aquifer. should this highly permeable aquifer provide a path around the dam, seepage losses could be very significant.

A monitoring network should be established in the valley aluvium and underlying Ravenscrag Aquifer below the dam to study potential soil salinity problems. The basal aluvium sand and gravel may be sufficient as a natural drain but also should be evaluated as a potential dewatering zone to reduce soil salinity.

652 Alameda Reservoir

Monitors should be installed in the valley aluvium below the proposed dam at the Alameda site. A small test drilling program could determine if the aluvium could provide a natural drain or if dewatering is required to avoid soil salinity.

The surficial drift deposits should be investigated as a potential source of leakage from the reservoir and possibly bank storage.

653 Rafferty - Boundary Diversion Channel

Because of the relatively small impact on the groundwater regime expected to occur as a result of the construction and operation of the diversion channel, no additional baseline data or monitoring is required.

APPENDIX A

WATER WELL INVENTORY SUMMARY

APPENDIX A - WATER WELL INVENTORY SUMMARY

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TABLE A-1

Summary of Water Well Records
Rafferty Reservoir/Shand Site Area

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
1	D. Hirsch	NE 32-03-06	10-10-80	D	4.7	454	281	110	289	2	X	R		D
2	M. Walter	NW 35-03-06	17-09-83	D	4.8	325	293	112	215	3	X	R		D
3	E. Mehler	SW 36-03-06	28-09-73	D	4.0	300	270	90	275	4	X	G		D
4	S. Hirsch	SW 01-04-06	23-07-81	D	6.3	420	348	112	351	4	X	G		D
5	S. Hirsch	SW 01-04-06	25-03-83	D	4.8	388	277	130	277	5	X	R		D
6	S. Hirsch	SW 01-04-06	01-11-83	D	4.8	295	273	130	277	3	X	R		D
7	M. Rohatyn	NW 02-04-06	15-11-78	D	4.5	300	270	125	270	2	X	G		D
8	I. Gibson	NW 04-04-06	17-09-82	B	40.0	34	13		36	10	X	G		D
9	P. Hirsch	SW 04-04-06	13-09-77	D	4.5	320	294	112	304	8	X	G		D
10	W. Schaft	NE 24-04-06	10-12-73	D	4.5	400	380	120	380	5	X	G	02-76	D
11	R. Miller	SW 31-04-06	21-09-83	B	40.0	32	23		27	3	X	G		D
12	E. Verobe	SW 33-04-06	01-12-72	B	42.0	23	10	10		2	X			D
13	M. Soroko	34-04-06	14-09-32	D	2.0	250	250	60	240		X	G		D
14	D. Schnell	NW 34-04-06	16-09-77	D	4.5	260	226		237	8	X	G		D
15	N. Sherman	SW 29-01-07	07-06-78	B	36.0	16	8	5	16	2	X	G		D
16	V. Morhart	SW 31-01-07	19-06-79	B		22			22		X	R		D
17	C. Peterson	NE 32-01-07	02-11-64	D	4.0	420	360		360	4	X	R		D
18	J. Kjersen	NE 36-01-07	16-05-79	B	42.0	61	30		20	4	X	R		D
19	R. Kinna	SW 03-02-07	17-04-78	B	42.0	92	62			5	X			D
20	G. Pooge	NW 04-02-07	30-11-74	B	30.0	28	16	16			X	R		D
21	R. Czoba	SW 09-02-07	18-05-46	J	2.0	470	404	80			X	R		D
22	J. Hagel	SW 06-04-07	09-11-68	D	2.5	345	295	40	305	2	X	G		D
23	H .Miller	NE 14-04-07	17-09-65	D	2.5	375	345	100	340	3	X	G		D
24	A. Fichter	NE 16-04-07	01-11-63	D	2.5	330	290	100	286	2	X	G		D
25	R. Wock	SW 18-04-07	20-10-77	B	40.0	25				2	X	G		D
26	A. Schaff	NW 24-04-07	11-10-77	B	42.0	41	18			3	X	G	03-76	D
27	A. Schaff Jr.	27-04-07	13-06-72	B	30.0	27	20	5		10	X	G		D
28	A. Fichter	NW 03-05-07	14-09-77	D	4.5	275	245		260		X	G		D

TABLE A-1
(Cont'd)

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
29	L. Hildal	NE 10-04-08	19-11-79	D	4.5	170	158	52	159	3	X	G		D
30	E. Lindgren	NE 12-04-08	05-12-45	J	2.0	328	294	98	292		X	R	12-63	D
31	H. Carlberg	SW 12-04-08	00	D		87		54				G	03-76	D
32	H. Carlberg	SW 12-04-08	02-06-62	D	2.0	225	200	98	203	1	X	G		D
33	S. Mack	SE 14-04-08	22-09-45	J	2.0	316	299	98	299		X	R		D
34	W. Davidson	NW 17-04-08	02-30	H		10		10			X	G		D
35	H. Miller	SW 22-04-08	27-10-82	D	4.7	200		30	155	30	X	G		D
36	Hamlet of Hitchc	SE 33-02-09	29-12-82	B	36.0	56	46	30	50	10	X	G		D
37	J. Muirhead	SE 34-02-09	00	B		63		24			X	R		D
38	L. Hingman	NE 09-03-09	25-04-78	D	4.5	200	125	120	157	10	X	G		D
39	D. Fiest	NE 21-03-09	23-03-81	D	4.5	305	200	142	242	2	X	R	11-63	D
40	P. Holzer	NE 28-03-09	07-71	D	4.0	170	150	150	140	5	X	G		D
41	E. Willie	NW 28-03-09	00	D		307		132			X	R		D
42	P. Holzer	SE 28-03-09	05-05-67	D	4.5	62	55	20	57	4	X	G		D
43	P. Holzer	SE 28-03-09	04-07-77	D	4.5	180	150	150	166	5	X	G		D
44	J. Besplug	SE 30-03-09	00	H		44		13				G		D
45	E. Mack	NW 31-03-09	00	D	2.0	250	218	100	245	2	X	R		D
46	H. Franck	NE 32-03-09	00	D		212		40	200		X	R	11-63	D
47	A. Friesen	SE 33-03-09	00	D	2.0	245	210		240	3	X	R	11-63	D
48	G. Evans	NW 03-04-09	22-06-74	D	4.5	31	16	9	26	3	X	G		D
49	E. Gervais	NE 06-04-09	00	D		290		122				G		D
50	W. Dixon	NE 08-04-09	00	D		278					X	G		D
51	W. Werk	NE 16-04-09	03-11-81	B	42.0	24					X	G	11-63	D
52	H. Neuman	SW 16-04-09	19-12-72	B	30.0	22	4	4		14	X	G		D
53	R. Mcgillicky	NE 18-04-09	00	B		40		13			X	G		D
54	A. Barreth	NE 20-04-09	00	D		285		10				G		D
55	O. Olson	SE 20-04-09	19-12-72	B	30.0	21	5	5		2	X	G		D
56	O. Olson	SE 20-04-09	00	D		275						G	07-73	D
57	J. Bachoreik	SW 20-04-09	30-11-77	D	4.5	300	223		239	6	X	R		D
58	Hjorteland	SW 27-04-09	04-07-73	D	4.5	100	87	18	90	10	X	G	12-63	D
59	H. Schram	SW 27-04-09	21-09-48	J		90	83	30			X	G		D

TABLE A-1
(Cont'd)

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
60	D. Bryson	NW 02-02-10	00	D		335		25	120			G	12-63	D
61	D. Bryson	NW 02-02-10	12-12-79	D	4.7	280	220	20	220	28	X	G		D
62	W. Barnstable	SW 04-02-10	00	D		380		85				G	03-76	D
63	R. Adams	NE 10-01-10	25-03-78	D	4.0	260	250	62	250	4	X	G		D
64	V. Adams	NW 11-02-10	74	D	4.0	225	200	50	210	10	X	G	12-63	D
65	L. Sovdl	SW 14-02-10	31-05-81	D		360	320	80	332	12	X	R		D
66	H. Adams	SE 15-02-10	00	B		72		44				G		D
67	Outram Community	19-02-10	03-10-77	D	4.5	365	350	65	356	65	X	G		D
68	R. Memory	NE 19-02-10	20-11-74	B	30.0	25	3	3		2	X	G		D
69	A. Soudie	NE 19-02-10	15-12-79	D	4.8	360	330	76	335	11	X	G	12-63	D
70	A. Soudie	NE 19-02-10	07-11-64	D	4.0	250	240	25	240	5	X	G	11-63	D
71	G. Whiteman	SE 22-02-10	00	D		345		45			X	G	08-58	D
72	A. Ness	NW 26-02-10	19-11-62	D	2.0	325	260	100	260	2	X	G		D
73	W. Collins	NW 29-02-10	00		2.0	210					X	G		D
74	W. Collins	NW 29-02-10	06-06-77	D	4.0	360	350		355	30	X	G		D
75	K. Memory	SE 29-02-10	04-80	D	4.5	380	230	63	245	15				D
76	L. Soudie	NW 30-02-10	14-11-77	D	4.5	367	354	60	357	20				D
77	L. Soudie	NW 30-02-10	20-05-81	B	42.0	33				5	X	G		D
78	A. Memory	SW 30-02-10	00-27			18	11				X	G		D
79	G. Tedford	NE 31-02-10	14-08-76	D	4.5	355	345	70	345	70	X	G		D
80	C. Mcleod	SE 03-03-10	10-07-63	D	4.7	37	37		24	3	X	G		D
81	B. Gillies	NE 06-03-10	02-11-81	B	42.0	50	26			8	X	G		D
82	G. Tedford	SE 06-03-10	15-03-79	D	4.7	410	390	63	390	20	X	G	12-72	D
83	V. Erikson	NE 07-03-10	02-08-77	B	42.0	36	16	14	38	10	X	G		D
84	F. Boyer	NE 10-03-10	09-11-62	D		150	140			8	X	G		D
85	H. Vanderhurk	NE 15-03-10	03-06-73	B	30.0	23	14	14		5	X	G	11-63	D
86	C. Steinke	SE 17-03-10	24-07-68	D	4.5	25			16		X	G		D
87	K. Memory	SW 18-03-10	21-11-74	B	30.0	41	16	16	41	5	X	G		D
88	C. Steinke	SE 22-03-10	23-10-62	D	2.0	150	137	80	150	1	X	G		D
89	C. Steinke	SE 22-03-10	02-09-76	D	6.2	220	149	80	152	3	X	G		D
90	Stoney Acres Far	NW 24-03-10	27-05-75	B	30.0	50	6	6	53	6	X	G		D

TABLE A-1
(Cont'd)

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
91	E. Blackburn	SE 28-03-10	08-06-65	D	4.0	206	200	87	206	15	X	G	11-63	D
92	R. Liese	NE 32-03-10	07-11-77	B	24	25			25		X	G		D
93	W. Stegger	SE 32-03-10	00	D		350						R		D
94	F. Frijout	SE 34-03-10	00	D		255		8	225		X	R		D
95	E. Foord	NE 01-04-10	16-11-77	B	42.0	60	26		59		X	G		D
96	E. Foord	NE 01-04-10	16-11-77	B	42.0	60	26		59		X	G	11-63	D
97	N. Blondeau	SW 06-04-10	03-06-75	B	30.0	24	6	6		5	X	G	08-47	D
98	W. Burnard	NE 11-04-10	00	H		30		16		15	X	G		D
99	A. Weinrauch	NE 06-02-11	00	H		12		12		8		G		D
100	C. Holzer	SE 08-02-11	26-06-81	D	4.5	305	200	66	287	10	X	R	5-74	M
101	A. Zimmerman	NW 17-02-11	15-12-76	D	4.0	240	220	100	220	2	X	R		D
102	Village of Torqu	NE 19-02-11	04-06-74	D	9.0	213	199	40	203	40	X	G		D
103	B. Bjorndalen	SW 20-02-11	05-06-81	D	4.5	300	245	80	247	10	X	R		D
104	H. Yergens	NE 25-02-11	10-10-42	J	2.0	360	180	80			X	G		D
105	H. Yergens	SE 25-02-11	27-03-78	D	4.0	370	360	0	358	50	X	G		D
106	P. Marcotte	30-02-11	19-11-62	D	2.0	220	180	60			X	G	12-63	D
107	M. Marcotte	SE 30-02-11	14-10-77	D	4.5	290	207	70	272	272	X	G	12-63	D
108	J. Salte	SW 08-03-11	00	B	30.0	24		12			X	G		D
109	R. Steinke	NE 09-03-11	24-10-62	D	2.0	178	140	40	145	2	X	G		D
110	R. Steinke	NE 09-03-11	28-10-77	D	4.5	250	152	50	170	8	X	G		D
111	R. Jones	NE 10-03-11	29-8-37	J	2.0	383	344	95			X	G	11-63	D
112	W. Steinke	NW 12-03-11	02-07-65	D	4.0	45	20	16	39	12	X	G		D
113	W. Steinke	NW 12-03-11	00	B		24		21				G		D
114	A. Gingrass	SW 13-03-11	22-11-71	B	30.0	62	18	18		15	X	G		D
115	A. Gingrass	SW 13-03-11	14-10-62	D	4.0	55	25	15	25	4	X	G		D
116	H. Bergum	NE 21-03-11	25-11-74	B	36.0	13	6	6	13	5	X	G		D
117	H. Girard	SE 23-03-11	22-11-74	B	36.0	14	8	8	14	5	X	G	11-63	D
118	H. Bergum	SE 28-03-11	22-11-74	B	36.0	26	14	14	26	5	X	G		D
119	H. Bergum	SE 28-03-11	25-11-74	B	36.0	24	9	9	24	5	X	G		D
120	Swenson	SE 28-03-11	00	H	36.0	22		15	22			G	11-63	D
121	Tangen Brothers	NE 22-04-11		D		40		12						

TABLE A-1
(Cont'd)

Well No.	Owner / Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
122	H. Ironside	NE 28-08-67	01-08-67	D	4.5	40	29	12	35	6	X	6		D
123	J. Penny	SE 28-04-11	00	H		22		5	22			6	03-76	D
124	J. Penny	SE 28-04-11	00-05-67	D	4.5	170	161	22	165	5	X	6	11-63	D
125	J. Penny	SE 28-04-11	12-04-68	D	4.0	300	290	40	295	7	X	6		D
126	J. Penny	SE 28-04-11	00	B		90		60				6		D
127	J. Penny	SW 28-04-11	08-11-62	D	4.0	66	60	15	66	2	X	6		D
128	H. Kuntz	NW 26-01-12	24-01-73	D	4.0	125	105	15	104	6	X	6	08-61	M
129	A. Wanner	SW 36-01-12	64	D	4.0	215	205		205	1	X	6	06-62	M
130	Town of Torquay	NW 24-02-12	04-05-61	D	4.0	180	150	20	151	12	X	R		M
131	Town of Torquay	NW 24-02-12	10-05-62	D	6.0	175	150	30	150	28	X	R		D
132	Town of Torquay	NW 24-02-12	07-71	D	6.0	170	155	119	150	40	X	R		D
133	Weyburne Securit	NW 22-04-12	12-11-[illegible]	D	5.0	325	109	105	141	3	X	R		D
134	Weyburne Securit	NW 22-04-12	26-02-76	D	4.5	90	77	13	80	5	X	6	06-72	D
135	Middle Comm. Pas	SE 03-05-12	23-08-62	B	30.0	14	10	10	14	3	X	6		D
136	E. Stabenow	SE 10-05-12	00		4.0	66		8				6		D
137	E. Stabenow	SE 10-05-12	06-06-72	D	4.0	66	50	29	61	10	X	6		D
138	Lutheran Bible C	20-05-12	10-06-83	B	42.0	48			50	10	X	6		D
139	B. Ziehl	NE 31-05-12	03-10-77	B		24			26	3	X	6	03-72	D
140	H. Wilgenbush	SW 31-05-12	17-08-61	B		35	30	29	35	5	X	6		D
141	L. Kramer	NE 32-05-12	03-10-77	D	4.5	118	115	10	113	5	X	6		M
142	Shell Oil	SW 04-06-12	01-07-61	D	6.7	277	268	40	267	3	X	6		D
143	Village of Halbr	NE 21-06-12	01-10-77	B		59		11	62	15	X	6		D
144	S. Lockridge	SE 21-06-12	28-06-62	D	6.7	93	15	7	61	3	X	6		D
145	Halbrite School	SE 21-06-12	13-07-62	B	30.0	30	19	15	30	1	X	6		D
146	Weyburn Scholl U	SE 21-06-12	07-07-62	D	6.7	65	53	18	53	4	X	6		D
147	D. Wilkerson	NW 16-05-13	11-81	B		24			26		X	6		D
148	D. Wilkerson	NW 16-05-13	22-10-82	B	42.0	34	10		36	6	X	6		D
149	D. McKenzie	NE 20-05-13	04-06-82	B	42.0	30			31	5	X	6		D
150	J. McKenzie	NE 20-05-13	13-09-83	B	42.0	29			31	12	X	6		D
151	D. McKenzie	NE 20-05-13	03-05-74	B	30.0	30	8	8	30	10	X	6		M
152	B. Wanner	SE 20-05-13	28-10-76	B	28.0	30	11	8	30	2	X	6		D

TABLE A-1
(Cont'd)

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
153	R.M. of Lomond	21-05-13	21-10-82	B	40.0	28	8		29	12	X	G		D
154	Weyburne School	21-05-13	28-07-78	B	30.0	27			27	6	X	G		D
155	Goodwater Mem. R	21-05-13	02-05-74	B	30.0	21	8	8	2	10	X	G		D
156	A. Ernest	NW 21-05-13	19-03-75	B	30.0	26	10	10	26	8	X	G		D
157	N. Jordan	SW 21-05-13	20-03-75	B	30.0	24	8	8	24	15	X	G		D
158	P. Ror	SW 21-05-13	20-03-75	B	30.0	25	10	10	25	10	X	G		D
159	R. Kerr	SE 30-05-13	24-03-81	B	42.0	38			38	2	X	G		D
160	C. Kerr	SW 30-05-13	23-03-81	B	42.0	40			39	2	X	G		D
161	J. Morricce	32-05-13	09-81	B	40.0	37			37	10	X	G		D
162	J. Morrice	NE 32-05-13	24-10-76	B	36.0	55	28	15	55	6	X	G	01-74	I
163	PanCan Petrol Lt	SE 05-06-13	30-09-71	D		3730		450	3373			G		D
164	F. Morrice	SW 05-06-13	25-10-76	B	36.0	35	22	24	35		X	B		D
165	L. Bakusko	NE 06-06-13	25-04-74	B	30.0	46	31	30	46	4	X	G	11-65	I
166	Central Del Rio	NW 16-06-13	22-01-64	D		3521	3342	400	3521	425		G	11-65	I
167	Central Del Rio	SW 16-06-13	01-12-63	D		3522	3336	400	3522	300		B	11-65	I
168	Central Del Rio	SW 16-06-13	06-12-63	D		3520	3342	400	3520	150		B	11-65	I
169	Central Del Rio	NE 17-06-13	30-01-64	D		3511	3330	400	3511	384		B	11-65	I
170	Central Del Rio	NE 17-06-13	20-01-64	D		3525	3322	400	3525	270		B	11-65	I
171	Central Del Rio	SE 17-06-13	27-01-64	D		3511	3340	400	3511	425		B	05-65	I
172	Central Del Rio	SE 17-06-13	27-01-64	D		3516	3344	400	3516	350		B		D
173	D. Alexander	SW 18-06-13	01-10-80	B	40.0	50	30		50	5	X	B		D
174	M. Freeman	NW 20-06-13	24-04-74	B	30.0	50	24	24	50	3	X	G		D
175	M. Freeman	NW 20-06-13	26-08-81	B	14.2	50			50	5	X	G		D
176	C. Freeman	SW 20-06-13	29-08-61	B	30.0	30	17	15	30	1	X	G		D
177	McKenzie Bro.	NE 21-06-13	02-10-80	B	4.0	19	7		19	10	X	G	09-71	I
178	PanCan Petrol Lt	SW 23-06-13	21-08-71	D		4400	3068	450	4400			G	12-73	I
179	Central Del Rio	SW 31-06-13	31-08-71	D		3428	3003	450	3428	118		D		D
180	V. Tabish	SE 01-07-13	09-64	D	7.9	155	95	45	96	2	X	B		D
181	R. Cuzndt	SE 30-07-13	22-11-72	B	30.0	24	12	12	24	4	X	R		D
182	G. Thackery	SE 25-05-14	12-07-73	B	30.0	59	40		58	3	X	G		D
183	G. Thackery	SE 25-05-14	27-10-70	B	30.0	50	18	16		5	X	R		D
												G		D

TABLE A-1
(Cont'd)

Well No.	Owner/ Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
184	G. Thackeray	SE 25-05-14	28-09-66	D	9.0	58	25	18	48	3	X	R		D
185	G. Rose	SW 25-05-14	26-04-74	B	30.0	81	45	39	81	10	X	G		D
186	B. Croal	NE 32-05-14	27-10-81	B	42.0	70			72	5	X	G		D
187	Weyburne Securit	SE 32-05-14	03-10-80	B	40.0	20			21		X	G		D
188	D. McLeod	NW 34-05-14	30-07-80	B	40.0	113	3		117	3	X	G		D
189	L. McLeod	NW 34-05-14	15-12-61	D	7.0	160	55	40	165	3	X	G		D
190	C. Lokken	NE 35-05-14	08-08-61	B	30.0	28	20	6	28	5	X	G		D
191	C. Lokken	NE 35-05-14	19-03-75	B	30.0	24	6		24	1	X	G		D
192	D. Rodine	SW 36-05-14	18-11-76	D		97			88	3	X	G		D
193	W. Thackery	SW 36-05-14	25-05-62	D	6.5	94	81	27	84	4	X	G		D
194	L. Beach	SW 03-06-14	09-11-59	D	4.0	140						G		D
195	F. Fisher	SW 09-06-14	17-06-82	D		90	45	28	81	3	X	G		D
196	F. Fisher	SW 09-06-14	18-06-82	B	42.0	41			43	5	X	G		D
197	A. Weyburn	SW 10-06-14	09-09-61	B	42.0	32	25	28	32	1	X	G		D
198	J. Irwin	NE 13-06-14	23-09-61	B	28.0	30	14	14	30	2	X	G		D
199	G. Alexander	SE 14-06-14	11-10-75	B	30.0	67	39	39	67	1	X	G		D
200	A. Beach	NW 15-06-14	25-07-80	B	40.0	68	18		71	3	X	G		D
201	R. Beach	NW 15-06-14	06-05-67	D	4.5	135	120	35	130	4	X	G		D
202	J. Klatt	SE 19-06-14	11-61	B	30.0	25	18	21	25	1	X	G		D
203	P. Benning	SW 21-06-14	19-11-64	D	7.9	124	103	15	119	3	X	G		D
204	E. Irwin	NE 24-06-14	29-10-60	B	30.0	18	10	10	14	3	X	G		D
205	E. Irwin	NE 24-06-14	27-08-81	B	42.0	67			69	5	X	G		D
206	E. Irwin	NW 24-06-14	30-08-59	D	6.3	55	11	10	25	2	X	G		D
207	O. Hall	SE 24-06-14	23-11-72	B	30.0	23	6	6	23	1	X	G		D
208	O. Hall	SE 24-06-14	23-11-72	B	30.0	20	8	6	20	1	X	G		D
209	J. Campbell	NW 28-06-14	28-10-60	B	30.0	20	10	10	20	5	X	G		D
210	J. Carson	NE 30-06-14	13-07-73	B	30.0	28	8	8	28	50	X	G		D
211	J. Carson	NE 30-06-14	27-06-75	B	30.0	31	9	9	31	8	X	G		D
212	D. Herberholz	NE 32-06-14	29-09-81	B	42.0	28			30	5	X	G		D
213	A. Williamson	NE 05-07-14	24-07-80	B	40.0	40	6		43	2	X	G		D
214	A. Sedloski	SW 06-07-14	23-03-66	D	4.5	24	19	12	24	2	X	G		D

TABLE A-1
(Cont'd)

Well No.	Owner / Tenant	Location W2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
215	R. Feliner	NW 12-07-14	30-11-73	B	36.0	23	11	11	23	1	X	6		D
216	R. Feliner	NW 12-07-14	14-10-70	B	30.0	37	17	10	37		X	6		D
217	T. Minard	NE 17-07-14	12-10-70	B	30.0	42	30	30	42	5	X	6		D
218	A. Adolphe	NE 19-07-14	11-11-64	D	719	254	215	36	249	3	X	6		D
219	G. Hulbert	SE 20-07-14	04-08-83	D	4.5	112	87		92	5	X	6		D
220	J. Vogel	SE 20-07-14	02-02-77	B		27			29	4	X	6		D
221	J. Gaab	NE 29-07-14	12-10-70	B	30.0	28	8	18	28	2	X	6		D
222	M. Giroux	NW 33-07-14	18-11-71	B	30.0	59	10	10		5	X	6		D
223	E. Maurer	SW 12-07-15	13-10-70	B	30.0	18	6	6	18	5	X	6		D
224	E. Maurer	SW 12-07-15	13-10-70	B	30.0	22	6	6	22	7	X	6		D
225	E. Maurer	SW 12-07-15	31-07-82	D	4.5	30	7	9	13	15	X	6		M
226	C. Endicott	NW 01-08-15	07-07-66	B	36.0	27	8	7	27	1	X	6		M
227	Canadian Customs	SW 03-01-08	48	D	4.0	150	145	76			X	R		D
228	Charlie McGillic	SE 07-01-08	1969	D	4.0	120	115	40		6	X	6		D
229	Cundail Farms	SW 13-01-09	1980	D		140	55	35			X			D
230	Otto Schmidt	SW 30-01-09	1963	D	2.5	100	60	50		2	X	6		D
231	Joe Blackburn	NW 34-01-09	1979	D	4.5	110	85	38	103	15	X	6		D
232	John Blackburn	NE 04-02-09	1976	D	4.0	120	110	38		15	X	R		D
233	Lloyd Shanner	NE 07-02-09	1922	P	2.0	200		124		1		6		D
234	Wayne Brokenshir	NW 08-02-09	1977	D	4.0	110	98	87.22	100	3	X	6		D
235	Anton Cossette	NE 08-02-09	1973	D	4.0	130		71.6	110		X	6		D
236	Cossette Brother	SE 17-02-09	1966	D	2.0	150	100	50	146		X	6		P
237	John Dowhanuik	NE 22-03-09	1960	D	2.0	300		60	250			6		D
238	Ronald Wock	SW 26-03-09	1977	D	4.0	60		18.2	50		X	6		D
239	John Bespflug	SE 30-03-09	1975	D	5.0	150	110.6	110.6	135	5	X	6		D
240	Matt Yoner	NE 12-02-10	1965	D	4.0	400		90		3		R		D
241	Carl Snyder	SW 10-04-10	1900'S	P	2.0	250		58.5		2		R		
242	Doug Penny	SE 28-04-11	1960'S	D	4.0	300	285	50	295		X			
243	Ole Hanson	SW 02-04-12	1920'S		2.0	400-500		80-90				6		

TABLE A-2
Summary of Water Well Records
Alameda Reservoir Area

Well No.	Owner/ Tenant	Location M2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available		Formation	Date of Chemical Analysis	Water Use
1	W. Morrow	NE 03-07-02	15-06-72	B	30	61	50	47		3	X	G			D
2	W. Morrow	NE 04-07-02	27-09-73	D	4.5	400	380	40	392	9	X	R			D
3	G.Bell	NE 04-07-02	14-12-62	B	24	15					X	G			D
4	C. Ross	SW 02-07-02	25-09-67	D	4.5	285	60		276		X	R			D
5	D. Ruten	SE 03-07-02	03-10-84	B		29					X	G			D
6	K. Arndt	24-06-02	00		4	160		30				G		01-73	D
7	D. McDonald	SW 22-06-02	20-09-73	D	4.5	435	415	61	427	12	X	R			D
8	K. McDonald	SW 22-06-02	08-10-63	D	3	370	350	45	288	2	X	R			D
9	K. McDonald	SW 22-06-02	25-10-61	D	2	297	286	42	235	2	X	R			D
10	A. Lesy	SE 16-06-02	31-07-68	D	6	183	165	35		5	X	G		02-76	D
11	B. Hume	NW 12-06-02	14-09-77	D	4.5	210	175		187		X	G			D
12	E.Hume	NW 12-06-02	23-09-42	D		200	200				X	R			D
13	E. Hume	SW 10-06-02	11-10-63	D	2	315	275	40		2	X	R			D
14	L. Rainprize	NW 36-05-02	24-07-80	B	42	23				3	X	G			D
15	J. Steffensen	NW 34-05-02	17-06-74	D	4.5	405	360		360	11	X	R			D
16	J.Steffensen	NW 34-05-02	10-07-61	D	2	290	245	35		1	X	R			D
17	J. Harvey	NW 30-05-02	02-12-67	D	4.5	321	240	69			X	R			D
18	D. McLean	SW 25-05-03	25-10-63	D	2	233	125	40	211	2	X	R			D
19	J. East	SW 30-05-02	25-09-80	D	4.7	370	314	57	320	5	X	R			D
20	J. East	NW 20-05-02	13-11-81	B	42	24				5	X	G			D
21	J. East	NW 20-05-02	02-12-60	D	2.8	305	300	35	300	3	X	R			D
22	J. Harvey	SW 28-05-02	27-06-81	D	4	329	319	30	322	6	X	G			D
23	Cobaar Bros.	NW 21-05-02	19-12-83	D	6.2	330	308	37	320	4	X	G			D
24	G. Mantel	NE 21-05-02	22-06-82	D	6.2	287	253	53	277	4	X	R			D
25	H. Frey	SE 25-05-02	31-08-81	D	7.5	151	143	30	146	2	X	G			D
26	H. Frey	SE 25-05-02	14-09-59	D	4	345	290	105	290	2	X	R			D
27	Runsor	SE 30-05-01	00			285	280	80			X	R			D
28	J. Colpitts	SE 30-05-01	02-09-76	D	4.5	390	320	85	345	7	X	R			D

TABLE A-2
(Cont.)

Well No.	Owner/ Tenant	Location M2M Sec Twp Rg	Date Drilled	Well Type	Diameter (in)	Depth (ft)	Water Found at (ft)	SWL (ft)	Casing Length (ft)	Recommended Pumping Rate (igpm)	Driller's Log Available	Formation	Date of Chemical Analysis	Water Use
29		NE 19-05-01	00											
30	H. Bos	NE 18-05-02	14-12-60	D	4.5	380	370	83			I	R		D
31		NE 18-05-02	00			278	257			3	I	R		D
32	V. Knebush	SW 13-05-03	08-11-63	D		300		80			I	R		D
33	C. Shepherd	SW 06-05-02	15-11-67	D	4.5	241	183	29	231		I	R		D
34	T. East	SW 06-05-02	01-12-61	D	2.8	265	265	40		4	I	R		D
35	T. East	SE 06-05-02	16-10-70	B	30	222	202	7			I	R		D
36	W. Sloan	SE 03-05-02	14-03-78	B	42	30	27			10	I	R	02-76	D
37	W. Sloan	SE 03-05-02	15-11-66	B	30	51	16			1	I	G	02-76	D
38	R. McLean	NE 26-04-02	20-06-73	D		24	17	16		20	I	G		D
39	R. Kolke	NE 26-04-02	26-08-64	D	4	285	253	70			I	G		D
40	R. Hayward	NW 12-04-02	03-07-81	D	4.5	63	45	30	45	3	I	R		D
41	Dillmore/Hassard	NW 19-04-02	02-11-63	D	4	371	355	108	363	3	I	G		D
42	H. Nichol	NE 31-06-02	29-10-63	D	2	272	260	87	267	2	I	R		D
43	B. Brown	SW 05-07-02	17-05-83	D	5	268	241	35	268		I	R		D
44	W.Brown	NW 05-07-02	06-05-74	D	4.5	390	360	86	380		I	R		D
45	A. Brown	SW 06-07-02	20-10-63	D	2.5	392	360	36	384		I	G		D
46	D. Nicholl	SW 08-07-02	15-07-76	D	4.5	275	268	35	275		I	R		D
47	A. Fruscott	NE 14-04-03	15-10-67	D	4	418	391	60	408		I	R		D
48	G. Whitfield	34-04-03	20-10-67	D	4	368	190	60	368		I	R		D
						265	140	30	265		I	G		D

APPENDIX B
MATHEMATICAL MODEL AND FLOW EQUATIONS

MODIFIED DARCY GROUNDWATER FLOW EQUATION

$$Q = K \frac{h A}{l}$$

where
- Q = Flow rate in m^3/day
- h = head of difference across flow length in metres
- l = length of flow path
- A = cross sectional area of flow path m m^2
- K = Hydraulic conductivity in m/day

ANALYTICAL ALGORITHM
(After Koch, 1986)

$$s(x',y') = (Q/2\ \ T)[\ln[(b + (c + b\ \ )\ \ )/c] - \cosh\ \ [H(x',y')]](2)$$

where

$$H^2\ \ (x',y') = (x'\ \ + y'\ \ + c\ \ + [(x'\ \ + y'\ \ + c) - 4x'\ \ c\ ]\ )/2c$$

and

$$b = 2[(Tt)/S]$$

and where
- s(x',y') = drawdown @ point x', y';
- Q = discharge;
- T = transmissivity;
- b = radius of influence;
- c = one-half the length of the line sink;
- x' = one component of the vector form the middle of the line sink to the point of intent
- y' = the other component of the vector from the middle of the line sink to the point of interest
- t = time
- S = storage coefficient

APPENDIX C

RAFFERTY AND ALAMEDA RESERVOIR
BASELINE DATA AND MONITORING REQUIREMENTS
FOR HYDROGEOLOGICAL MITIGATIONS

RAFFERTY AND ALAMEDA RESERVOIRS
BASELINE DATA AND MONITORING REQUIREMENTS
FOR HYDROGEOLOGICAL MITIGATIONS

1.Ø INTRODUCTION

Baseline data gathering and subsequent monitoring are required to formulate and implement a mitigation policy with respect to the potential hydrogeologic impact that may result with the construction of the Rafferty and Alameda Reservoirs.

The proposed reservoirs may affect the groundwater regime such that the following problems may arise:

- Collapse of water well casings as a result of increased hydraulic head.
- Changes in water quality; both chemical and physical.
- Increase in soil salinity.

2.Ø BASELINE DATA REQUIREMENTS

2.1 RAFFERTY RESERVOIR

a) Estevan Valley Aquifer

There are sufficient monitor wells presently in place so no additional work is required to properly monitor the potential impact on this aquifer.

b) Weyburn Valley Aquifer

Because of the relatively minor impact expected to occur with respect to this aquifer it is recommended that only one monitor well be installed. A suitable location would be the NW1\4 or NE1\4 of 24-4-12-W2M.

c) Ravenscrag Aquifer

The impact on hydraulic head and water quality of this aquifer may be widespread (up to 1Økm). It is recommended that 4 monitor wells be installed in the area of greatest expected impact.

The increased hydraulic head in the Ravenscrag Aquifer may cause soil salinity problems below the dam. It is recommended that 3 monitor wells, spaced at about 5ØØ metres, be installed in this aquifer downstream of the dam.

d) Valley Alluvium

This particular unit should be monitored for potential leakage and soil salinity problems. It is recommended that at least 4 monitor wells be installed in the alluvium at a spacing of about 500 metres below the dam. It is also advisable to obtain some preliminary information regarding the ability of the basal alluvial sand and gravel deposit to act as a natural drain or as a potential collector for dewatering. Six testholes should be sufficient to obtain this data.

e) Tableland Aquifer

Due to the high permeability associated with this aquifer significant leakage problems around the dam and large changes in water levels at great distances may occur. As a result, it is recommended that a test drilling program be done to determine if a hydraulic connection with the proposed reservoir could exist.

Since very little is known about the extent of this aquifer in the vicinity of the Souris Valley it is difficult to predict the actual amount of work that may be required to delineate it. It is estimated that as many as 20 testholes to a depth of 60 metres each may be required. If a hydraulic connection with the proposed reservoir is found to exist, at least 4 monitor wells may be required to study the potential impact of the Rafferty Reservoir.

2.2 ALAMEDA RESERVOIR

a) Ravenscrag Aquifer

The Alameda reservoir will have very little impact on this aquifer and it is therefore recommended that only one monitor well be installed near the proposed dam to observe the maximum potential effect if any.

b) Surficial Drift

In combination with terrace deposits and valley alluvium, this particular unit has a very high potential to conduct water around the reservoir. This aquifer will also be affected the greatest in terms of water level increases and changes in water quality.

It is recommended that a test drilling program consisting of up to 20 testholes (15 metres deep) be initiated in the area of the proposed dam to better predict the potential for the above problems to occur. Once the extent of this aquifer is known, then up to 6 monitor wells may be required to observe the effects of the Alameda Reservoir.

c) Intertill Aquifers

At least one intertill aquifer on each side of the reservoir should be monitored. Four testholes to 43 metres deep may be required to find suitable zones in the vicinity of the proposed dam.

d) Valley Alluvium

Preliminary indications are that the valley alluvium is quite permeable. This may be quite beneficial in preventing increased soil salinity below the dam but it may be a cause for concern with regards to seepage under the dam.

Six testholes may be required to determine if the alluvium can laterally dissipate any increase in groundwater discharge below the dam. Two monitor wells downstream of the dam should be sufficient if no salinity problems are anticipated.

2.3 Water Analyses

All monitor wells installed to observe the impact that the Rafferty and Alameda reservoir may have on the groundwater regime, should be sampled and analyzed for the following parameters:

Major Constituents

CO_3, Ca, Cl, HCO_3, K, Mg, Na, SO_4, TDS, Alkalinity, Hardness, N (N, NO_2 + NO_3), C, OH

Trace Constituents

Boron, Cyanide, Fluoride, Mercury, Selenium, Sulfide, Sulfide Mercaptan

Metals

Ag, Al, As, Ba, Be, Bi, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Sn, Sr, U, V, Zn

Physical Properties

Color, Conductivity and pH

2.4 Well inventory

It is recommended that a well inventory be conducted to include all wells, springs and dugouts within a 10 kilometer radius of each of the proposed reservoirs. Should it be shown that the Tableland Aquifer is hydraulically connected to the Rafferty reservoir, then this distance should be extended to 20 kilometers for this aquifer only.

Samples should be collected for each water source found during the inventory and analyzed for major ions only. More detailed analyses would be considered for select wells or water sources where significant changes in the groundwater regime are expected.

3.0 MONITORING

3.1 Water Levels

During each spring runoff period, all monitor wells at each reservoir should have water levels checked twice per month for two months. Between runoff periods, water levels should be measured at least every month. This schedule should be maintained until the reservoir is full after which time a once every other month schedule should be in place for at least 3 years.

3.2 Groundwater Quality

All monitor wells should be sampled annually for major ion analysis. Repeats of the detailed analysis are not recommended unless the major ion testing shows significant changes in water quality.

4.0 COST SUMMARY

Charges for drilling services are based on average prices submitted by competent Saskatchewan drilling contractors for similar projects undertaken by Beckie Hydrogeologists Ltd. during the last quarter of 1986. Unit prices are provided in Appendix A.

Charges for engineering supervision of drilling, water level monitoring, water sampling and preparation of engineering reports are based on hourly charges (1987) for personnel of Beckie Hydrogeologists Ltd..

Detailed cost estimates for the work described in Section 2.0 and 3.0 can be found in Section 5. The following is a summary of cost estimates.

4.1 BASELINE DATA

Preparation and Mobilization	.....$5040.00
Test drilling and installation of monitor wells	....$113,354.00
Water analyses (detailed for monitor wells)	.....$11,700.00
Water Well Inventory (150 - 250 sources, including water analyses)	$24,900-$39,340
Report	.....$10,000.00
Total	$164,994 - $179,434

4.2 MONITORING (During filling of Reservoir)

Water levels	.....$11,200/year
Annual Water Sampling	.....$2,700/year
Water Analyses (Monitor Wells Only)	.....$780/year
Quarterly Report	.....$3,200/year
Total	$17,880/year

SECTION 5.0 DETAILED COST ESTIMATES

5.1 BASELINE DATA

a) Preparation and Mobilization

Estimated Contractor's Costs	$2000.00
Estimated Engineering Fees and Expenses	
Hydrogeologist 5 days	$2400.00
Junior Engineer 2 days	$640.00
Total	$5040.00

b) Test Drilling and Installation of Monitor Wells

(i) Rafferty Reservoir

Drilling Contractor Charges

Item	Amount	Unit Price	Total
Test drilling and E-logging	1774m	$11.50/m	$20,401.00
51mm ID steel pipe (installed)	640m	$19.70/m	$12,608.00
51mm ID screens	15 only	$100 each	$1,500.00
Frac sand (12-20 size)	58 sacks	$20/sack	$1,160.00
Drilling mud	140 sacks	$15/sack	$2,100.00
Cement	63 sacks	$12/sack	$756.00
Developing	60 hours	$80/hour	$4,800.00
Cementing	33 hours	$90/hour	$2,970.00
Standby	10 hours	$80/hour	$800.00
Extra Work	15 hours	$90/hour	$1,350.00
Sustenance	27 crew days	$120/crew day	$2,835.00
	Total		$51,280.00

Engineering Fees and Expenses

Hydrogeologist	18 days	$12,960.00
Junior Engineer	14 days	$6,720.00
Expenses		$4,000.00
	Total	$23,680.00

(ii) Alameda Reservoir

Drilling Contractor's Charges

Item	Amount	Unit Price	Cost
Test drilling and E-logging	600m	$11.50/m	$6,900.00
51mm ID steel pipe (installed)	293m	$19.70/m	$5,772.00
51mm, ID, screens	11 only	$100 each	$1,100.00
Frac Sand (12-20 size)	46 sacks	$20/sack	$920.00
Drilling Mud	100 sacks	$15/sack	$1,500.00
Cement	36 sacks	$12/sack	$432.00
Developing	48 hours	$80/hour	$3,840.00
Cementing	12 hours	$90/hour	$1,080.00
Standby	8 hours	$80/hour	$720.00
Extra Work	11 hours	$90/hour	$990.00
Sustenance	15 crew days	$120/crew day	$1,800.00
	Total		$25,054.00

Engineering Fees and Expenses

Hydrogeologist	10 days	$7,200.00
Junior Engineer	8 days	$3,840.00
Expenses		$2,300.00
	Total	$13,340.00

c) Water Analyses

Detailed Water Analyses for 26 monitor wells
Estimated Laboratory Fees (SRC) $11,700.00

d) Well Inventory

Estimated 150 to 250 wells to be monitored, including water analyses (Prov. Health Lab).

Estimated Engineering Fees and Expenses

Hydrogeologist 5 to 8 days	$2,400 - $3,840
Junior Engineer or Technologist, 35-55 days	$14,000 - $22,000
Field Expenses	$4,000 - $6,000
Water Analyses	$4,500 - $7,500
Total	$24,900 - $39,340

d) Report

Estimated Engineering Fees and Expenses:

Hydrogeologist	10 days	.....$4,800.00
Junior Engineer	15 days	.....$4,800.00
Expenses		.....$400.00
	Total	$10,000.00

5.2 MONITORING

a) Water Levels

Estimated Engineering Fees and Expenses:

Junior Engineer or Technologist	14 days	.....$7,280.00
Expenses		.....$3,920.00
	Total	$11,200.00

b) Annual Water Sampling

Estimated Engineering Fees and Expenses:

Junior Engineer or Technologist	5 days	.....$2,000.00
Expenses		.....$200.00
	Total	$2,700.00

c) Water Analyses

Major ion analyses for 26 monitor wells:

Estimated Lab. fees (Provincial Health Lab) $780.00

d) Quarterly Report

Estimated Engineering Fees:

Hydrogeologist	4 days	.....$1,920.00
Junior Engineer	4 days	.....$1,280.00
	Total	$3,200.00